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*WHO MADE THE MASSACHUSETTS CONSTITUTION?**

BY W. P. ATKINSON, A.M.

To answer this question I must begin by recalling to your memories events that are narrated in all your school-books. I need not tell for the thousandth time the story of the famous "Boston Tea-Party," which took place one hundred and fifteen years ago (Dec. 16, 1773), "the boldest stroke" wrote home the royal governor, "that has yet been struck in America." The subsequent events are all familiar to you, — the closing of the port of Boston, the sending of Gage and four regiments, the violent proceedings of the British Parliament against the remonstrances of such wise and far-seeing statesmen as Burke — all this you read in all the histories. Let us keep our eye on Boston and Massachusetts, and see *just how* the transition was effected from the old to the new regime.

General Gage, the new governor, arrived in Boston May 17, 1774, and was received very respectfully. "He landed at Long Wharf," says my history,† "and was received with great parade. The principal officers of the government, the selectmen of Boston, and a number of other gentlemen were in attendance, with the company of cadets, and amidst the discharge of cannon from the admiral's ship and from the north and south batteries, he was escorted through King Street, where the troop of horse, the artillery company, the grenadiers, and other military companies were drawn up to salute him. On his arrival at the council chamber his commission was read and the oath of office administered by

* From a course of lectures on English and American Constitutional History.

† Barry's Massachusetts II., 480.

the president of the council. A proclamation was then issued continuing all the officers in their places; three volleys were fired, three cheers were given, and the governor was escorted to Faneuil Hall, where 'an elegant dinner was provided for his welcome,'" of which you may read in the *Boston Post-Boy*, though I fear the reporting was not up to the standard of the present times.

All this was very pleasant on the surface, but alas! all was quite different underneath. Governor Gage was obliged to proclaim the port of Boston closed. At 12 o'clock, June 1, the doors of the custom-house were locked and the courts suspended. The people took no notice except by tolling all the bells, but organization was everywhere quietly proceeding, and everywhere the Liberty Song was heard to the tune of Rule Britannia:—

"Be not dismayed!
Though tyrants now oppress,
Though fleets and troops invade,
You soon will have redress;
The resolution of the brave
Will injured Massachusetts save."

Writs were issued in September convening the General Court in October, not in Boston, but at Salem; but before October arrived, Governor Gage issued a proclamation dissolving it. This was the last ounce that broke the camel's back. The members assembled in spite of the governor's proclamation, resolved themselves into a Provincial Congress, in imitation of that Continental Congress which had meantime assembled at Philadelphia, and from that moment Governor Gage was no longer Governor Gage, but simply a rather red-faced Englishman, walking about in a cocked hat. It is from this point that the independence of Massachusetts begins, and every step taken by that Provincial Congress becomes of the greatest interest. I thought myself very fortunate in finding in a second-hand bookstore this copy of the volume of its proceedings, printed by the State in 1837, at the suggestion of Edward Everett, who was then our governor.* It has already become a scarce book, and every page of it is full of interest. It is the sort of book that I urge you to examine for yourselves, for such books form the raw material of history, and by the study of them one learns to be himself a historical inquirer. The very list of the delegates is interesting to a Massachusetts man, for here from every town come men with names identified with that town's history from its very first settlement; from

* Journal of the Provincial Congress of Massachusetts in 1774 and 1775, and of the Committee of Safety, etc. Boston, 1838. 8vo. pp. 778.

Roxbury, Capt. William Heath and Mr. Aaron Davis; from Brookline yonder, Capt. Benjamin White and Mr. John Goddard. It would be a curious inquiry how many of these names still survive in the various towns of the Commonwealth.

I wish time allowed me to go into the details of the proceedings by which these sturdy ancestors of ours, sitting, for aught they knew, with halters round their necks, first at Concord, where they invited the minister of the town, the Reverend Mr. Emerson (grandfather of Ralph Waldo Emerson), to be their chaplain, and afterwards at Cambridge, organized their revolutionary government.

It was this assembly, spontaneously gathering at the will of the people themselves, that was recognized by the people who had chosen them as the only supreme authority during the war. The other legal and governmental machinery remained undisturbed; the taxes continued to be paid, though the power that had hitherto controlled had passed entirely away. It shows what an intelligent and law-abiding people they were that they could thus extemporize a new authority in place of the missing one, and calmly continue on their way. It is in striking contrast to the hideous chaos of confusion, the massacre, and all the bloody work of faction that was so soon to follow on the other side of the Atlantic, in the shape of the first French Revolution. It was the difference between the doings of a community accustomed, and of another wholly unaccustomed, to self-government.

It could not but be, however, that they should soon feel the want of a more regular and organized system, and accordingly we find that as early as 1776 a proposition was made that a committee should be appointed to prepare a form of government. Accordingly, in September the Legislature adopted a resolution to advise the people to clothe the members of the next general court with full powers to frame a constitution, and a majority of members were so chosen, though there was a very general opinion that a special convention should be called for so grave a work. A joint committee, however, did frame a constitution, which was approved by the Assembly and sent out to the people for ratification. Here, however, it met with much opposition; and especially at a meeting in Essex County a remarkable paper was presented by a young lawyer named Parsons who afterwards rose to be chief justice of the State, — a document which was widely circulated and had great influence. Perhaps it is not too much to say that it was this paper which caused the rejection of the plan, and it is curious to see how early party divisions began, for this document may be called the first manifesto of New England Federalism.*

* It is printed in the appendix to Professor Parsons' Life of his father.

This attempt having proved abortive, the Legislature of 1779 put the question to the people whether a convention should be called for the express purpose of framing a constitution; and the question being answered in the affirmative, such a convention was chosen and met September 1, 1779, in Cambridge, adjourning afterwards to the Old State House in Boston; but it is curious now to read that by reason of the very bad travelling it was a long time before a quorum could assemble.

The journal of the convention itself is a meagre document. It was before the days of shorthand reporters and lightning presses, and none of the speeches are given. Meagre as it is, however, it is by no means without interest for the careful reader. It was printed by order of the Legislature in 1832, but it is still scarcer than the other volume just mentioned. I have repeatedly tried in vain to procure a copy. It has a certain degree of personal interest for me, for in it I found the name as a delegate from the old town of Newbury, in Essex County, of my maternal grandfather. I should like to put the book in my study alongside of the old dragoon sword which my other grandfather girded on, when, as lieutenant of the company from old Newbury, he hastened to join the Continental army that was besieging Boston, to the command of which a promising young Virginia land-surveyor, named Washington, had just been appointed.

The roll of this constitutional convention, like the one that preceded it, is full of old Massachusetts names, and many of their bearers rose to great distinction. I pass every day, on my way home, through a territory now covered with tenement houses and breweries, the spot where stood, in the days of my youth, the pleasant country-seat of a family that has given so many eminent names to the State, and has been so identified with the establishment of one of our leading industries, — the Lowell family. Another distinguished name, connected in later years with the neighboring town of Brookline, deserves a passing notice. In the year 1690 there was born in Limerick, at the very time when William of Orange was besieging it, a child named John Sullivan. He belonged to a famous old Irish family, the O'Sullivans, Lords of Bearehaven. This John Sullivan in after years, when he had grown to man's estate, was involved in a plot of the Duke of Ormond to restore the Stuarts, and had to flee to America, where, in 1722, he had settled down in what was then the wilderness of Maine, and what is now the town of Berwick. Here he lived on his great farm to the patriarchal age of one hundred and four, educating his own sons and daughters, and the other children

of the neighborhood, himself; and he must have been a very remarkable man, for the biographer of his grandson says, that without any other educational advantages than the teaching of their father his sons proved able to cope with college graduates and with the leaders in the trying times of the Revolution, as lawyers and statesmen. One of these sons was General John Sullivan, of the Revolutionary army; another, James, who was a member of this constitutional convention, was twice afterwards elected governor of Massachusetts. His son was the late Hon. Richard Sullivan of Brookline.*

It was in 1779 that this Massachusetts Constitutional Convention met, eight years before the meeting of the convention that framed the United States Constitution. The war was not over, and it was a striking evidence of their confidence in their cause that they could engage in such a work when the aspect of affairs was so gloomy. Clinton was in possession of New York, and Washington had nothing to do but patiently to watch him. The attempt of Lincoln, aided by the French fleet, to capture Savannah had proved a disastrous failure, and the hopes that had been excited by the French alliance had begun to fade. The brutal Tryon was plundering Connecticut, and the little fleet that had been sent to capture Castine had just been itself captured and destroyed. Yet it was in the midst of this gloom that the Massachusetts men thus calmly met together to construct for themselves a permanent frame of government. Who would be found in that miscellaneous body capable of building the political edifice? It needed something more than good sense and good judgment, of which, no doubt, there was plenty; it needed far-seeing sagacity, and, above all, political knowledge. A common carpenter can build a cottage, but it is only the trained architect who can build a great and stately edifice to stand for centuries. Had these ancestors of ours any such political architect among them? The hour had arrived: where was the man?

To find him we must look back some years. In 1755, twenty-four years before, there had graduated at little Harvard College, — very small and humble it was then, — at the age of nineteen, the son of a farmer in Braintree. His ancestor had been one of the first settlers of the town, and when he died had bequeathed a house of three rooms, three beds, a cow, and *one silver spoon* to his children. But the family had prospered and were held in high esteem; and now this youth, with such an education as could be had at Harvard in those days, was going out to seek his fortune. Now, in the first book of Massachusetts laws,

* See Memoir of Hon. Richard Sullivan, by Thomas C. Amory, in Vol. IV. of the "Memorial Biographies of the New England Historic Genealogical Society."

made while Massachusetts was a colony, and only seventeen years after our fathers had settled in the wilderness, there stood this enactment: "To the end that learning may not be buried in the graves of our forefathers in church and commonwealth, the Lord assisting our endeavors; it is therefore ordered by this court and authority thereof that every township in this jurisdiction, after the Lord hath increased them to the number of fifty householders, shall then appoint one within their town to teach all such children as shall resort to him to write and read. . . . And it is further ordered, that when any town shall increase to the number of one hundred families or householders they shall set up a grammar school, the master thereof being able to instruct youth as far as they may be fitted for the university;" that is to say, in Latin and Greek grammar and a little Hebrew. Now, in 1755 the town of Worcester, though not the great city it is now, had increased to one hundred families, and was bound to establish what, following the English fashion, they then called a grammar, but what we should now call a high, school; and hearing of this young graduate from Braintree, they engaged him to come and keep it; and to enable him to get to Worcester they sent a horse down for him to ride through what was then still pretty much a wilderness. Now, if you will look at your history, you will find that these were stirring times, though it was a good while before our Revolution. It was the time of what we call the French and Indian War, a war of immense importance in European history; for by it was finally determined the question whether the colonization of North America and the possession of India should belong to a representative of the Latin or south European races, the French; or to the representative of the Teutonic or north European races, the English. It was a war waged all over the world, and to understand its magnitude and significance you must read it in the history of Europe, not merely in the history of America. But the operations in America, though, with the exception of the capture of Quebec, comparatively insignificant, made a great stir in the American colonies themselves, and the very year when our young schoolmaster is making his way through the woods on horseback to Worcester, foolish General Braddock is getting thrashed in the forests of Virginia, in that action in which that young Virginia land-surveyor before mentioned showed such remarkable coolness and bravery. How little could these two young men, — one defending his life against Indians in the Virginia forest, the other with his clothes and a book or two in his saddle-bags riding through the woods of Massachusetts, — how little could they dream of the great destiny fate had in store for them!

Our youngster, duly installed in office, writes this burlesquely grandiloquent account of his situation to one of his friends: —

"WORCESTER, 2 Sept., 1755.

"I promised to write you an account of the situation of my mind. The natural strength of my faculties is quite unsufficient for the task. Attend, therefore, to the invocation, O thou goddess, Muse, or whatever is thy name, who inspired Milton's immortal pen with a confusion ten thousand times confounded, when describing Satan's voyage through chaos, help me in the same cragged strains to sing things unattempted yet in prose or rhyme. When the nimble hours have tackled Apollo's coursers and the gay deity mounts the eastern sky, the gloomy pedagogue arises frowning and lowering like a dark cloud begrimed with uncommon wrath to blast the devoted land. When the destined time arrives, he enters upon action, and as a haughty monarch ascends his throne, the pedagogue mounts his awful *great chair* and dispenses right and justice through his whole empire. His obsequious subjects execute the imperial mandates with cheerfulness, and think it their high happiness to be employed in the services of the emperor. Sometimes paper, sometimes his penknife, now birch, now arithmetic, now a ferule, then A, B, C, then scolding, then flattering, then thwacking, call for the pedagogue's attention. At length, his spirits all exhausted, down comes pedagogue from his throne and walks out in awful solemnity through a cringing multitude. In the afternoon he passes through the same dreadful scenes, smokes his pipe, and goes to bed. Exit Muse."

Plainly, he was not built for a schoolmaster. "The school," he says in another place, "is indeed a school of affliction." But while thus drudging at a task for which he clearly shows he had no aptitude and no love, he writes a remarkable letter showing how profoundly political events were affecting him, though little could the youth of barely twenty, as he sat in his pedagogue's chair and governed the little world of his schoolroom, dream of the great part he was soon to play on the wide stage of the great world's history.

He determines to adopt a profession, but does not know which to choose. Those were the primitive days when the schoolmaster was "boarded round," and the selectmen put him for a time into a doctor's family, and he dipped into the doctor's medical books, but does not seem to have liked them. His invincible repugnance to the gloomy doctrines of Calvinism, the only theology then current in New England, prevented him from becoming a preacher. He wrote afterwards that he would have entered the army — the British army, of course — if he could have obtained a commission; but he becomes more and more interested in law, and at length, as there were no law-schools in those days, Lawyer Putnam agrees to take him as a law student, for the board the town allowed, and a hundred Spanish dollars, which he was to pay *whenever it was convenient.* Then for two years more he kept school for six

hours a day, and dug away at the grim old law-books in the evening, and it was well that he and all his race had vigorous constitutions. Then he is admitted to the bar, and comes back to live with his mother and practise law at Braintree; and presently marries Miss Smith, the daughter of the minister of Weymouth, and an admirable wife the minister's daughter of Weymouth proved to be.

But there is nothing very remarkable in all this, you say. There are plenty of young men to-day who keep school for awhile, study law, and then settle down as country lawyers, and marry their neighbors' daughters. Could one predict beforehand, which among them, in case of some great political emergency, would come to the front as a great and sagacious and patriotic leader of the people? Certainly such men sometimes spring up in most unexpected places. Nature has something to do with the making of them, for they must be large-brained men; but they have a great deal to do with their own making, for they must be something more. A large-brained man may become a skilful lawyer, and make a fortune by his practice at the bar, but yet he may be *nothing but* a practising lawyer. He may know only such parts of the law as he has use for, such as are most needed in the routine of the courts: many know the law only as an art to get money by. He is nothing but a practising lawyer, and, however good as such, can never be anything else. Another may be skilled in the law in a different and far higher way. He has studied the law as a part of the great science of society, knows well that part of it that is useful in gaining cases in the courts, but knows a great deal more, — the law as it was in past times and the law as it is in other countries and among other peoples; knows the law, in short, not merely as a money-getting art, but as a great and important branch of liberal learning.

Well, our young law-student was a lawyer of this latter kind, one who had not been content with acquiring a rule-of-thumb knowledge of a few law-books. He had profoundly studied the subject of the forms of government in different ages and nations, as he showed by a book he afterwards published. The law-books he read would make some students of our day shudder, and so it was by no accident that when the dispute with the mother-country broke out, and the people looked about for wise guides and skilful leaders, the young Braintree lawyer should be found constantly at the front, or that all sorts of tasks that required judgment and wisdom as well as disinterested patriotism should be entrusted to him; or that when at last a successor in the presidential chair at Washington was sought for, he was found in one of the foremost statesmen of the day, once the young pedagogue of Worcester, and that his name should be John Adams.

I have dwelt at such length on the early history of John Adams, because, in addition to all his other splendid services to his country, Massachusetts owes almost entirely to him the drafting of her constitution. Professor Parsons claims, somewhat hesitatingly, and on the strength of tradition, the merit of originating some clauses for his father, afterward the distinguished chief justice; and Mr. Samuel Adams Wells, in the life of the ancestor for whom he was named, is disposed to claim much of the merit of its authorship for him; and he prints the address of the convention recommending the new constitution to the people, which was written by the famous "Man of the Town Meeting." Both these eminent men were members of the sub-committee appointed to draw it up, and I have no doubt that if any record were left of their consultations, the conservative lawyer and the sturdy patriot, who was the very incarnation of democracy, would both be found to have been sagacious advisers. But outside the lids of his Bible Sam Adams was an unlettered man; and here was a work that required political knowledge, and his namesake and distant kinsman, John Adams, was far away, the best publicist of his day. "Beyond all his associates," says Governor Bullock in his excellent address before the American Antiquarian Society,* "in mastery of the whole subject of government, grasping and applying the lessons of historical studies with a power at that time unprecedented on this continent, and adding to them the original conceptions of a mind of the highest order, he proved of all his contemporaries fittest for constitutional architecture." Whether Governor Bullock is right in exalting him so high above Madison and Hamilton may be a question; but he himself had no doubt of the merit of his work. When, eight years after, that illustrious convention assembled which framed the United States Constitution, he was abroad as Minister to England, but he claims even there the influence of his work. He says in a letter which has come to light, "I made a constitution for Massachusetts which finally made the Constitution of United States."

However this may be, what is certain is, that he put together a constitution for us in such solid and workmanlike fashion, that it has remained virtually unchanged to this day, the oldest constitution in the country. Of all the constitutions now in force, two only besides ours date back to the eighteenth century: that of New Hampshire, adopted in 1792, and that of Vermont, dating from the year after; and it is safe to say that these are substantially copies of our own. Our own has

* "The Centennial of the Massachusetts Constitution," in Transactions of the American Antiquarian Society for 1881.

remained but little altered. There was a provision that at the end of fifteen years the question should be put to the people whether they desired any alteration, and they voted that they did not. Forty years after, in the year 1820, in consequence of the district of Maine being erected into a State, a constitutional convention was called, and John Adams again appeared and was elected its president; but by reason of the infirmities of age — he was eighty-six — he declined. Here Daniel Webster, then thirty-eight years old, first came to the front, and we find many names familiar to us of the older generation in our boyhood, Story and Shaw, and Prescott and Quincy. But little change was made by this convention in the organic form of the constitution. In 1853, another constitutional convention was called, whose proceedings fill three bulky volumes, and which attempted various innovations, but their work when submitted to the people was rejected. In the last sixty years twenty-seven separate amendments have been adopted, some of them of comparatively trifling importance, and none of them altering one fundamental principle on which it is founded. Massachusetts bears the palm for conservatism, having now lived one hundred and seven years under the same constitution, while only seven other States have succeeded in living under the same constitution for half a century. Four States have had five constitutions apiece, Georgia, South Carolina, Texas, and Virginia, while Louisiana is living under her sixth. It is noticeable that biennial sessions of the legislature have been substituted for annual, in twenty-five constitutions, including all the later ones, an example which, with all our conservatism, it would be wise for us, it seems to me, to follow.

Of the general character of the new constitutions Mr. Horace Davis of San Francisco says, in an excellent pamphlet in the Johns Hopkins Series,* in which he has examined the subject, "The desire to control and limit the government is shown throughout the general character of these new constitutions. It extends in some respects, though in a limited degree, to the powers of an executive and the judiciary, and it forms a striking contrast to the generous confidence which the people placed in their officers a century ago, and the liberal powers entrusted to them. The early instruments were usually very short, being often simply a bill of rights followed by a mere skeleton of the government. Those of to-day are lengthy documents, full of detail, frequently more like a code of laws than a fundamental instrument."

* "American Constitutions — the Relations of the Three Departments as adjusted by a Century," being IX.–X. Third Series of the "Johns Hopkins University Studies in Historical and Political Science."

It seems to me that it may be open to question whether this tendency pointed out by Mr. Davis is wholly in the right direction. Undoubtedly it is intended as a check upon hasty and contradictory legislation and the multiplication of useless laws. But on the other hand it tends to obliterate the distinction that should exist between constitutional law and ordinary legislation, and often to make a part of the permanent law some provision which may turn out to be only the craze of the hour. In one Western constitution there is a solemn constitutional provision respecting grain-elevators, while another State has attempted to make prohibition successful by a prohibitory clause in its very constitution. Is there not danger in this direction of bringing constitutions and constitutional law into contempt?

I have thus given you a brief account of the framing of the Massachusetts constitution itself. At our next meeting we will consider the history of some of the provisions of the Bill of Rights that is prefixed to it.

AN INDEX TO THE LITERATURE OF THE BUTINES AND THEIR HALOGEN ADDITION PRODUCTS (1863–1887).

By ARTHUR A. NOYES.

In making this compilation, I have not only been led by the desire to contribute a little to the general subject of chemical indexing, which, in view of the vast and constantly increasing literature of that science, must be regarded as a task of no little importance; but also I have hoped to throw a clearer light on the constitution of the different butines, in regard to which great confusion exists in almost all the text-books. I have endeavored to make this index as complete as possible in original literature, fully realizing that its value must largely depend on this; yet, as I have not been able to consult the indexes of all the chemical periodicals, a list will be given below of those to which reference has been made, in order that it may be clear to what extent this index can be considered complete. It is especially probable that the Journal of the Russian Chemical Society contains some additional statements.

The theory of the structure of organic compounds requires the existence of four isomeric hydrocarbons of the composition C_4H_6; namely: $CH_2 : CH . CH : CH_2$, vinylethylene; $CH_2 : C : CH . CH_3$, methylallene; $CH : C . C_2H_5$, ethylacetylene; and $CH_3 . C : C . CH_3$, dimethylacetylene. The literature of these compounds dates from 1863.*

In that year, Caventon, by the action of bromine on the products of the decomposition of amyl alcohol by heat, obtained a solid tetrabrombutane melting at 114° to 115°. A tetrabromide, apparently identical with this in every respect, has been since obtained from butines from various other sources: by Prunier, from the butine resulting from the action of heat on a mixture of ethylene and acetylene; by Caventon, from that in illuminating-gas; by Henninger, from that produced from erythrol by reduction; by Armstrong and Miller, from that existing in compressed oil gas; by Roscoe,† from that in the low boiling distillates

* Bouchardat, it is true, obtained in 1838 (Am. Chem. 27, 33), by the distillation of caoutchouc, a hydrocarbon boiling at 14°.5, which is classed as a butine in some of the text-books; apparently without sufficient reason, however, for its vapor density was not determined, and the analyses agree with the formula C_nH_{2n}, which differs from C_4H_6 by 3.2 per cent.

† Helbing, to be sure, obtained from the low boiling distillates from coal tar, a bromide showing a melting-point of 99°. It is highly probable, however, as Caventon supposed, that this low melting-point was due to insufficient purification.

from coal tar; by Ciamician and Magnaghi, from trimethylpyrrolylammonium iodide and potassium hydroxide; and also, from the butines produced by the action of heat on low boiling petroleum, hexane, pentane, ethylene, and isobutylene. The identity of the butine from illuminating-gas with that from erythrol has been confirmed by Grimaux and Cloez, who showed that the tetrabromides of these two butines not only agree in melting-point and general appearance, but also that they give, on treatment with alcoholic potash, a dibrombutine which unites with bromine to the same tetrabrombutylene and hexabrombutane in the two cases. Ciamician and Magnaghi, also, have proved the identity of their pyrrolylene with the butine from erythrol, for both give with bromine the same two tetrabromides, one melting at 118° to 119°, and the other at 39° to 40°.

The constitution of this butine is properly regarded as one of the well-established facts of organic chemistry. That it is vinylethylene is evident from the following considerations: first, its non-precipitation by ammoniacal cuprous chloride,* which excludes ethylacetylene; second, its formation from erythrol† by reduction; third, the identity of the chlorine and bromine addition products of the butine with the tetrachloride† and tetrabromide‡ produced by the action of phosphorus pentachloride and bromide on erythrol; and fourth, its oxidation § to formic acid by potassium permanganate. The statement of Prunier, which has been copied by most of the text-books, that ethylacetylene is formed by the action of heat on a mixture of ethylene and acetylene, is obviously incorrect; for Berthelot states that the butine obtained in this way is not absorbed by ammoniacal cuprous chloride. It should also be mentioned here, that the conclusion of Baswitz and Aronheim, that a butine is formed by the action of sodium on vinylbromide, is probably erroneous, for they themselves give no evidence justifying it, and Fuchs obtained from the same action only ethylene and acetylene; moreover, S. P. Mulliken, who investigated the subject last year in the Organic Laboratory of the Institute, obtained, by combining the products of the action with bromine, ethylene, acetylene, and bromethylene bromides, but no butine tetrabromide.

The butine obtained by Lermontoff by the action of sodium ethoxide on the brombutylene derived from pseudobutylene bromide by the removal of hydrobromic acid, was shown by Almedingen, in 1881, to be dimethylacetylene; for, in contact with sulphuric acid, it polymerizes to hexamethylbenzene. Consequently, also, the butine which

* Caventon.
† Henninger.
‡ Colson.
§ Armstrong and Miller.

Caventon obtained in 1863, was probably mainly dimethylacetylene, though, as he started with an impure butylene bromide, it is not unlikely that his product was a mixture of isomers. Moreover, as the bromine addition product of angelic acid, $CH_3 . CHBr . CBr(CH_3) . COOH$, would probably give on distillation the brombutylene $CH_3 . CH : CBr . CH_3$, identical with that obtained by Lermontoff, it is reasonable to regard Jaffé's butine, which was separated from this brombutylene by the action of potassium hydroxide, as dimethylacetylene. Finally, as Wurtz has pointed out, the butine obtained by Pfankuch, by the distillation of barium acetate with sulphur, must have been dimethylacetylene, and not divinyl, as the latter states, unless it is assumed that a rearrangement of the atoms occurs in this reaction.

Ethylacetylene has been prepared* synthetically only by the withdrawal of two molecules of hydrochloric acid from the chlorides formed by the action of phosphorus pentachloride on methylethylketone and butaldehyde. The only proofs of its constitution are the methods of its formation, and its precipitation by ammoniacal silver and copper solutions.

Methylallene tetrachloride was obtained, some years ago, by Garzarolli-Thurnbackh from $\alpha_2\beta$ trichlorbutyl alcohol and phosphorus pentachloride. Last year, from this tetrachloride, by the action of the zinc-copper couple, I obtained the butine itself.† Its method of formation is satisfactory evidence of its constitution.

The foregoing statement will be sufficient, I think, to show the extent of our present knowledge of these hydrocarbons, and to indicate the reasons for the classification of the different references adopted in the index.

In the compilation of the index reference has been to the text-books of the following authors: Berthelot, Beilstein (1885), Bloxam, Hodgkinson and Greenaway, Kekulé, Kolbe-von Meyer, Laubenheimer, Miller, Roscoe and Schorlemmer, Schützenberger, and Wenghöffer; also, to the Dictionaries of Fehling, Ladenburg, Watts, and Wurtz, to Carnelly's Melting and Boiling Point tables, and to Richter's Tabellen der Kohlenstoff-Verbindungen.

The indexes of the following periodicals from 1863 to 1887 inclusive, have also been consulted: Am. Chem. J.; Ann. Chem.; Ann. der Phys. Pogg.;‡ Ann. chim. phys.; Ber.; Bull. Soc. chim.; Chem. News; Chem. Centrbl.; Gazz. chim. ital.; Jsb. Chem.;§ J. Chem. Soc.; J. Gas-

* Bruylants, in 1875, was the first to obtain it.

† An account of this investigation will soon appear in the American Chemical Journal.

‡ Volumes 121–150 only.

§ Up to 1884 only.

beleucht. Wasserversorg.; J. prakt. Chem.; J. Soc. Chem. Ind.; Monatsh. Chem.; Recueil trav. chim.; Rep. chim. appl.; Rep. chim. pure.; Ztschr. anal. Chem.; Ztschr. Chem.

Explanation of the Index.

The index consists of two parts, — an Index of Authors, alphabetically arranged, and an Index of Subjects, primarily classified under the heads of the different butines.

The former index gives in the first column the authors' names in alphabetic order; in the second, references to the periodicals; and in the third, the dates of publication of the original articles. The references to the articles published by the authors themselves are printed in Roman type, while reprinted or abstracted articles are in italic.* The abbreviations used are those provisionally recommended last year by the Committee on Indexing Chemical Literature of the American Association for the Advancement of Science. Those references marked with an asterisk I have not been able to consult in the original. In some few cases abstracted articles give statements additional to those made in the original; this has been indicated in the index by a dagger placed after the reference.

In the Index of Subjects, as stated above, the subjects are primarily classified under the heads of the different butines, and subdivided under these in the manner and order usual in text-books; that is, under Constitution, Occurrence, Formation, Physical Properties, Reactions. The halogen addition products are found under the heads of their corresponding butines, and are subdivided in the same manner. The numbers preceding the authors' names in this index refer to the articles in the Index of Authors.

In conclusion I desire to express my thanks to Mr. G. R. Tucker for his valuable assistance in the publication of this index.

Index of Authors.

1	Almedingen.	Zhurnal Khim.* **13**, 392. *Jsb. Chem.* 1881, **359**; *Ber.* 14, **2073**; *Bull. Soc. chim.* 37, **493**.	1881
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* It should be mentioned that no great pains have been taken to make the list of reprinted and abstracted articles complete.

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1 Wurtz, A.	Ann. chim. phys. (5) **1**, 557.	1874

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I. BUTINES OF DOUBTFUL CONSTITUTION.

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* Grimaux and Cloez obtained in the distillation of vinylethylene tetrabromide an isomeric bromide, which they consider to be probably dimethylacetylene tetrabromide. See 3 Grimaux and Cloez and 1 Ciamician. There is no evidence, however, to support this supposition.

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NITRO-BENZYL HYDROXYLAMINES.

By P. S. BURNS and J. P. GRABFIELD.

The present investigation, of which this paper is a partial record, had for its object the preparation and identification of the ortho-, meta-, and para-nitro-benzyl hydroxylamines. The examination of the condensation products of these isomers, and of the products of their decomposition on boiling, together with their action on other bodies, will form the subject of a succeeding paper.

It has been observed * that benzyl acetoxim decomposes on boiling, though the decomposition products were not isolated. From this decomposition of the analogue and from the structural composition of the nitro-benzyl hydroxylamines, it was anticipated that these compounds would give interesting side products.

The general method of producing the above compounds was as follows:—

Ortho- and para-nitro-benzyl chlorides were prepared after the method † for the preparation of the meta-nitro-benzyl chloride by treating a chloroform solution of nitro-benzalcohol with phosphorous pentachloride. This method was found to give an excellent yield.

The nitro-benzyl chlorides thus formed were treated with acetoxim and sodium alcoholate, giving the nitro-benzyl acetoxim. This treated with hydrochloric acid gave the corresponding salt of nitro-benzyl hydroxylamine, which on treating with sodium carbonate gave an oil, presumably the free base. In this manner the ortho and meta compounds were obtained, but on applying the same process to the para-nitro-benzyl chloride, di-nitro-stilbane was produced.

Ortho-Nitro-Benzyl Acetoxim.

The molecular quantities of ortho-nitro-benzyl chloride and acetoxim were dissolved in absolute alcohol, and to this solution was then added the molecular amount of sodium alcoholate. The mixture was heated in

* Janny and Victor Meyer (Berichte, D. C. G. 16).

† Geigy and W. Koenigs (B 18–2401).

a flask, with a return condenser attached, on the water bath for several hours, or until the oil, obtained by throwing a small amount of the solution in water, showed no trace of chlorine. The whole was then thrown into a large volume of water, the oil separated out and distilled with steam. The milky distillate was extracted with ether, and the ether evaporated on the water bath. The oil thus obtained was of a light yellow color, heavier than water, boiling at 148° to 150° at 80mm. pressure, undergoing slight decomposition, but which decomposed almost entirely on boiling at the ordinary pressure. The oil has a pleasant aromatic odor, is soluble in alcohol and ether, and insoluble in water.

An analysis for nitrogen gave: —

Found.	Theory for $C_{10}H_{13}N_2O_3$.
12.92 per cent N.	13.46.

The action may be represented as follows: —

$$\begin{matrix} CH_3 \\ | \\ CO=NOH \\ | \\ CH_3 \end{matrix} + NaOC_2H_5 + C_6H_4{}^{NO_2}_{CH_2Cl} = \begin{matrix} CH_3 \\ | \\ C=NOC_7H_6NO_2 \\ | \\ CH_3 \end{matrix} + C_2H_5OH + NaCl.$$

Acetoxim — Sodium alcoholate — Nitro-benzyl chloride — Nitro-benzyl acetoxim

On oxidizing the ortho-nitro-benzyl acetoxim with alkaline potassium permanganate, a crystalline body, melting at 145°, was obtained, which was in every way identical with ortho-nitro-benzoic acid.

ORTHO-NITRO-BENZYL HYDROXYLAMINE HYDROCHLORIDE.

On boiling the ortho-nitro-benzyl acetoxim with a concentrated aqueous solution of hydrochloric acid, complete solution took place, and on evaporating the solution on the water bath colorless acicular crystals were obtained. The crystals were dissolved in absolute alcohol, from this solution reprecipitated by the addition of ether, and dried over sulphuric acid. An analysis of the salt thus prepared gave, for chlorine: —

Found.	Theory for C_7H_9NOCl.
17.21 per cent Cl.	17.35 per cent Cl.

This hydrochloride is very hygroscopic, readily soluble in water and alcohol, and insoluble in ether. It melts at 97° to 100°, decomposing on further heating. An aqueous solution of the salt readily reduces Fehling's solution, one of the properties of hydroxylamines.

The production of nitro-benzyl hydroxylamine hydrochloride may be represented as follows: —

$$\begin{array}{l} CH_3 \\ | \\ CNO-C_7H_6NO_2 \\ | \\ CH_3 \end{array} + H_2O + HCl = \begin{array}{l} CH_3 \\ | \\ CO \\ | \\ CH_3 \end{array} + \begin{array}{l} OC_7H_6NO_2 \\ | \\ NH_2 \\ | \\ HCl \end{array}$$

Ortho-nitro-benzyl acetoxim — O- Nitro-Benzyl hydroxylamine hydrochloride

On treating the aqueous solution of the hydrochloride with sodium carbonate, effervesence took place and an oil separated out. The oil immediately redissolved on acidifying with chlorhydric acid. This was probably the free base,

$$N \begin{cases} OC_7H_6NO_2 \\ H_2 \end{cases}$$

Meta-Nitro-Benzyl Acetoxim.

On treating meta-nitro-benzyl chloride with acetoxim and sodium alcoholate, after the same manner as that described for the preparation of the ortho compound, an oil of a light yellow color was obtained, which, however, not being volatile with steam, was purified by distillation. Most of the oil came over at 198° with a pressure of 72mm., undergoing but very little decomposition. The analysis of the distillate at 198° gave for N :—

Found.	Theory for $C_{10}H_{12}N_2O_3$.
13.51 per cent N.	13.46 per cent N.

It gave, upon oxydation with potassium permanganate, a crystalline body slightly soluble in water, melting at 142°, which properties show it to be meta-nitro-benzoic acid.

Meta-Nitro-Benzyl Hydroxylamine.

On boiling the meta-nitro-benzyl acetoxim with an aqueous or alcoholic solution of chlorhydric acid, it undergoes an analogous decomposition to the ortho compound, forming a body crystallizing from alcohol in long needles, which, after drying over sulphuric acid, melt at 178°.

This hydrochloride readily reduces Fehling's solution.

The analysis for Cl gave :—

Found.	Theory for $C_7H_9N_2O_3Cl$.
17.14 per cent Cl.	17.35 per cent Cl.

Para-Nitro-Benzyl Acetoxim.

On treating para-nitro-benzyl chloride, in a similar manner to the ortho- and meta-chlorides, with acetoxim and sodium alcoholate, a yel-

lowish crystalline body was obtained, which melts at 280°, somewhat soluble in hot glacial acetic acid, and which gave on analysis for N: —

Found.	Theory for $C_{14}H_{12}N_2O_4$.
10.36 per cent N.	10.29 per cent N.

These and other properties, as volatility, prove the body to be para-di-nitro-stilbane.

The action was then tried by dissolving the acetoxim and para-nitro-benzyl chloride in ether, and then adding metallic sodium in small pieces: di-nitro-stilbane was also formed in this case.

Again, the action was tried, by adding to the para-nitro-benzyl chloride dissolved in benzol, sodium acetoximate. Di-nitro-stilbane was formed as before.

An attempt was then made to form the para-nitro-benzyl acetoxim by nitrating benzyl acetoxim, on the supposition that the para body would be among the nitrated products. The nitration was conducted after the usual method of dropping the fuming nitric acid into the chloride at a temperature below 0°. The nitration was also tried by using potassium nitrate and sulphuric acid. No nitro-benzyl acetoxim in either case was formed, the principal product being benzoic acid.

A FEW HINTS ABOUT DRAINAGE.

By F. W. CHANDLER.

In the selection of a site for the country house, however great the attractions may be, avoid any not well drained naturally. Much can be done by artificial drainage, but any ordinary filling only raises the finished surface a few feet more or less above the wet which is difficult to drain away. This applies particularly to level lands, as on a slope drains may be laid that will lead the water to the surface at a lower grade than the bottom of the house cellar.

On the other hand, the soil may be perfectly dry, but hard and clayey, land that in the spring time makes the plastered walls of the cellar damp, and wet spots to show perhaps, on the cellar concrete; for after heavy rains, because the soil will not leach, the water will follow down along the house and easily find an entrance through the ordinary cellar wall. This is land perfectly healthful to live on, if it can be drained to take care of the few wet months, for during the long summer everything is perfectly dry. If there is a public sewer, both the sewage and this water can be taken care of satisfactorily. If there is no public sewer, then reliance must be placed on the cesspool. In considering either case, the draining of the cellar wall is the first part of the system to be arranged for in the order of building. The bottom of the wall begins commonly from twelve to eighteen inches below the finished cellar floor. The trench from the outside of the cellar wall to the bank should be at least twelve inches wide at the bottom and two feet at the top; this allows plenty of room to examine the building of the wall, to see that it is carefully pointed to shed water, or to see that the outside of the wall is thoroughly plastered with clear cement, — a valuable precaution to take with a wet soil. At the bottom of this trench the drain-pipe is laid, and above this the filling may begin with small stones, gravel free from clay, or sand, allowing eighteen inches at the top for loam. In the laying of this drain-pipe care must be taken to have a regular fall to the outlet: the grade may be as little as one in four hundred and be effective. The highest point of this drain-pipe should be at the bottom of the footing stone of cellar wall, and the lowest point nearest to the sewer or cesspool, as the case may be. The drain-pipe used for this work should not be the agricultural tile drain so com-

monly used, but should be of second quality glazed pipe four inches in diameter, as advised by Mr. Ernest W. Bowditch. This second quality is perfectly strong, but the glazing is imperfect, or it may be twisted, or the hub cracked or broken, all faults of no consequence in this work. In regard to expense, this second quality costs less than the ordinary drain-tile. The great advantage of this pipe is the security of a large, clean aperture effected by the hub. The tile drains are only two or three inches in diameter, and are usually laid from one-quarter to one-half inch apart; this aperture is covered with tarred paper or cloth to prevent the earth working in, and then the trench is filled up; but with the greatest care taken, these tiles often get entirely choked up, and the porosity of the tile amounts to nothing. Mr. Bowditch has been called upon a number of times as an expert to find a reason why the cellar walls and floors should be wet, when the system of drain-tiles had been laid in the most thorough manner, and has invariably found the choking up of the tiles with earth to be the cause, and has replaced the same with the four-inch glazed pipe with entire success. This pipe should be laid with the hubs pointing downwards, as a better protection against earth entering the joints, which are of course uncemented. When the trench is carefully graded, it is better in laying this pipe to cut out still more of the earth for each hub, to insure an even bed for the pipe; and when the entire circuit of the walls is made, and the two ends joined to make one outlet, this must be entered into a trap, and this connection made as thoroughly as possible with clear cement. Whether this drainage pipe enters into the trap, or is led out to the surface at a lower level, it is important that a copper wire netting should be so placed as to prevent rats or other vermin entering, as they might if the pipes became dry: this netting should be put into the end of the second length, so that the last length can be crowded against it, and so insure its remaining. The trap must hold a large amount of water to guard against too rapid evaporation: it should be at least two feet and a half in diameter, with fourteen to sixteen inches' depth of water. It may be built of brick laid in cement, or it may be of one of the patterns now found in the market. The outlet from this to the drain must begin with a bend which should lead down to almost touch the bottom, and where passing through the wall of trap must be cemented in the most thorough manner, and the rest of this outlet pipe must be laid carefully in cement, the hubs pointing upward to its connection with the sewer—this outlet pipe being of the best glazed pipe.

It must be borne in mind that during the summer months the soil will probably be entirely dry, the water in the trap will naturally evap-

orate, the seal be thus lost, and sewer gas then have free entrance through trap and inlet, and so about walls of house. To avoid this danger, it is best to lead one of the rain-water conductors from roof into this trap, and as a further precaution, as in case of a drought, build a chimney from trap to top of ground with an iron cover, so that it can be filled by a hose or other artificial way. In this case the rain-water conductors should each have an S-trap, or a larger one if possible, at its foot, to lead into a system of their own similar to that draining the walls, the final outlet to enter wall waste-pipe beyond the trap. It must be understood that the work thus described is from necessity, not choice, as in every case where it is possible to do so this sub-soil drainage should be led to lighter soil, where it can leach away and be a system of its own, not even connecting with a sub-soil sewage system: in which case there need be no trap; but do not omit the copper wire netting before spoken of. It may be found as the work progresses that at times water comes up through the cellar floor, and this must also be taken care of. Such a floor must be covered with at least six inches of broken stone throughout, besides the finish of concrete; but in addition a graded trench should be dug, say six inches deeper at the lowest part, and twelve inches wide: this trench should be the whole length of the inside walls running parallel with them, and say twelve inches away. At the lowest part of this trench put in a trap, and from this trap lead a four-inch iron pipe with bend, turned down to almost touch bottom, and lead the other end through the outside wall into trap above water line, if waste must finally enter sewer, or into the sub-soil drain of a water conductor if the overflow is allowed to leach into the soil. This cellar trap is made by the Akron and Portland Companies, and seems to be all that is wanted. It is of glazed earthenware, with an iron cover, about sixteen inches in diameter and two feet long. It is a regular cylinder, and the upper half is perforated with small holes, and when the trap is sunk so that the cover is flush with finished floor, these perforations are opposite the broken stone stratum through which filters the water. It very rarely happens when the walls are properly drained that there is any appearance of wet on the cellar floor, but this is a very valuable expedient for an old building where the foundation walls are so poorly built that the earth cannot be removed from the outside of them to put the drains there, without endangering its stability, or for any cause where it is not desirable or feasible to put in the outside drain. The inside drain will do the work perfectly well, but of course it would be better if this dampness were outside the cellar walls.

One could hardly wish to build where all these precautions are neces-

sary, and it might be said that such conditions are rare; but there might happen even a more complicated case where there is no sewer, and tight cesspools must be used either because the earth will not leach, or there is not area enough to allow of sufficient sub-soil drainage. In this last case there must be a cesspool for the sewage, and another for the cellar drainage: pumps should be fixed over them, and they must be emptied regularly.

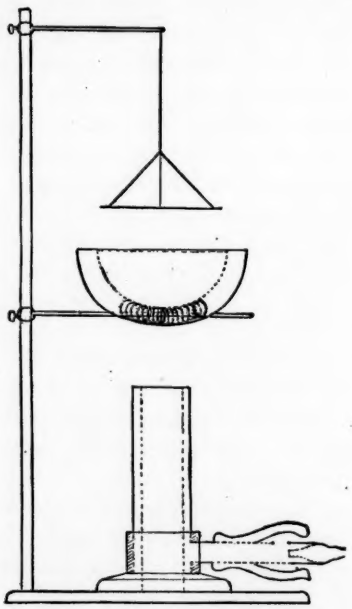
Thus far there has only been considered the drainage necessary for a dry cellar, and the mode of entering the soil pipe into the sewer is too well known to need further explanation; but in the case where the sewage can be disposed of by sub-soil drainage, the method as carried out by Mr. Bowditch seems by far the best, and this method was also devised to take the place of the intermittent flushing tank with its system of main and lateral tile-drains, which may under favorable circumstances work well enough, but cannot be relied upon. The same difficulty obtains in this case as about the cellar walls: the small pipes are too easily choked; more or less of the system thus becomes inoperative, the drainage becomes too concentrated, and the first sign of failure is the appearance of wet on the surface of ground — it "fountains up." Then, again, the complication of flush tank should be avoided in every case, until a better reason for using them is found than now exists: they are liable to, and do, get out of order. The system, as carried out by Mr. Bowditch, is to have a tight cesspool at least fifty feet from the house, into which is led the soil-pipe and overflow from grease-trap. This cesspool should be three feet in diameter and five feet high, and the inlet should enter at the top, and the outlet to run out say three feet from the bottom, so that all solid matter shall remain in the cesspool, which must be cleaned out occasionally. Of course the connection of house with cesspool must be of the best pipe and with tight joints, but the outlet is to be built of the second quality of glazed pipe, as before spoken of, to be five inches in diameter, laid with the hub pointing downwards. If the soil will allow it, Mr. Bowditch digs trenches for the main and lateral drains from three to four feet deep, say ten inches wide at bottom and eighteen inches at top. This trench is then filled in with broken or small stones, so that when the pipe is laid on them, there shall be eighteen inches of loam over the top of pipe. The lateral drains are put in twenty to twenty-five feet apart, and their length is limited by the size of the land; for example, a lateral of one hundred feet might be enough; but if it were found insufficient, the main should be continued twenty feet and another lateral built on; and gates are put in so that the sewage may be directed into any lateral desired, to give

others a rest. If the topography of the land is favorable, it is a good plan to lead a waste-pipe from bottom of cesspool out to the lower slope, where a compost heap is collected, and allow the entire cesspool to run out at regular intervals. The pipe in the trenches should be placed as near the surface of ground as possible, but not so near as to endanger its working in winter. Eighteen inches of soil is not too deep for the air to penetrate, and its oxygen is doubtless more effective in the purification of sewage than the action of plant life. During the winter, the one is of course inoperative, and the other must be very much hindered by the frozen ground, so that during this time sewage must be got rid of principally by leaching.

ON THE "LOSS ON IGNITION" IN WATER ANALYSIS.

By THOMAS M. DROWN, M.D.

The loss of weight resulting from the ignition of the total solid residue of evaporation of a water was, before the introduction of modern methods of water analysis, supposed to represent the amount of organic matter present in the water. It is now known that this loss, as ordinarily obtained, by heating the platinum dish containing the residue



with the free flame of a Bunsen burner, is a very uncertain quantity. Two chemists will often get widely different results, in consequence of varying practice in the temperature employed and the time of heating.

In order to eliminate this personal equation, as well as to control the temperature of the ignition, I make use of a large platinum dish as a radiator, inside of which the dish containing the residue is heated.

The above sketch shows the arrangement. The radiator is $4\frac{1}{8}$ in.

in diameter and 2 in. deep. The dish in which the water residue is heated is one inch less in diameter, and rests on a coil of platinum wire, half an inch high. A triangle of platinum wire may be used instead of the coil. A flat disk of platinum foil is suspended one inch over the inner dish, in order to radiate back the heat and hasten the combustion of the organic matter. The radiator is maintained at a moderate red heat by means of an argand gas-burner.

Careful experiments have proved that when solutions of sodium chloride, potassium nitrate and calcium carbonate, either alone or in solution together, are evaporated to dryness and heated in this way for half an hour or more, there is no loss in weight. When carbonaceous matter, like sugar, is burned off in the presence of calcium carbonate, the latter loses no carbon dioxide. Organic matter would doubtless decompose nitrates, but the quantity of nitrates present in surface waters is so small that the weight of the fixed solid residue would seldom be affected by their partial or entire decomposition. In fact, nitrates are to some extent reduced to nitrites by the heat of the radiator alone, when no organic matter is present; but the amount of this reduction is generally too slight to be appreciated by the balance.

The following determinations were made on the same sample of filtered Cochituate water, in order to compare the loss on ignition in the radiator with that obtained by cautiously heating the dish to dull redness with the Bunsen burner held in the hand. In both cases the brown residue of evaporation was heated until the carbonaceous matter was completely burned off, leaving a white residue; and after this ignition, the residue was moistened with a dilute solution of ammonium carbonate, dried, and the residue again very gently heated to drive off the excess of ammonium salt.

Amount taken.	Loss in Radiator. (Parts per 100,000.)	Loss over Free Flame. (Parts per 100,000.)
100 cc.	1.20	2.00
200 cc.	1.10	1.95
200 cc.	1.10	1.75
200 cc.	1.15	1.65
500 cc.	1.10	1.70
1000 cc.	1.17	1.77
1100 cc.	1.18	1.68

These results show that not only is the loss much lower in the radiator, but that it is much more uniform.

It has been found that moistening the ignited residue with ammonium carbonate solution is unnecessary when the ignition is carried out in the radiator, since no carbon dioxide is driven off; moistening with water and

drying at 100° C. answers the purpose — restoring any water of combination which may have existed in the total residue — quite as well.

The determination of the total solid residue and loss on ignition in ground waters is an entirely different problem from that presented in surface waters. In uncontaminated ground waters there is little or no organic matter, and the mineral matters, consisting in part, it may be, of lime, magnesia, chlorine, and nitric acid, are generally present in large amount. On the evaporation of a solution of this character to dryness there is loss of chlorine due to the decomposition of the magnesium chloride, and the solid residue is difficult to weigh owing to its deliquescence. On ignition there is loss of water of crystallization and of chlorine and nitric acid; indeed, the "loss on ignition" under these circumstances bears no relation whatever to organic matter.

This difficulty can be remedied by adding an amount of sodium carbonate solution, of known strength, to the water in the platinum dish before evaporation, sufficient to make it slightly alkaline. The lime and magnesia are then precipitated as carbonates — compounds which are not deliquescent, do not contain any water of crystallization, and are permanent at the temperature to which they are exposed in the radiator. The chlorine and nitric acid combine with the alkali and give compounds which are likewise permanent. When the "loss on ignition" is obtained under these conditions in ground waters, or in the effluents from the purification of sewage by filtration, it will represent approximately the organic matter. In good ground waters the loss is nothing. The amount of sodium carbonate added is, of course, to be deducted from the weight of the total and fixed residue.

One cannot expect the same sharpness of results in determining the solid matters and loss on ignition in water analysis as is obtained in the determination of the nitrogen compounds. If 200 cc. of water are taken for evaporation, an error of weight of one milligram is equivalent to 0.5 part in 100,000. When we consider the number of conditions which may affect the weight of the residue of evaporation, both before and after ignition, — such as the temperature of the air bath, the time of heating, the character of the residue, the hygroscopic condition of the atmosphere, the condition of the air of the laboratory, whether containing much dust, or acid or ammoniacal fumes, — the lack of agreement among chemists in this simple determination is not surprising.

The practice in the chemical department of the Massachusetts Institute of Technology is as follows: Two hundred cubic centimetres of a surface water, or one hundred of a ground water which contains considerable mineral contents in solution, are evaporated to dryness on a water

bath in a hood which is used for no other purpose. To the ground water is added, if necessary, sodium carbonate, as above described. When the water is all evaporated, the platinum dish is placed in the air bath, connected with the water bath, for about one hour. The temperature of this air bath is 95° to 98° C. The dish is then transferred to a desiccator and cooled over sulphuric acid for half an hour: it matters not how long it stays in the desiccator after it is cool. It is then weighed, and in order that the residue may not absorb moisture during weighing, there are placed in the balance case four beakers of sulphuric acid, which is frequently renewed. This is essential in those cases in which the residue has a tendency to absorb moisture. The dish is next heated in the radiator until all the organic matter is burned off, moistened with water, and put again into the air bath, that it may be, at the second weighing, precisely under the conditions as at the first weighing.

The loss of weight in surface waters, which blacken on ignition, may, under these conditions, be regarded as a close approximation to the organic matter present, both vegetable and animal; and the residue, or "fixed solids" represents, fairly well, the mineral matters of the water.

Massachusetts Institute of Technology,
November, 1888.

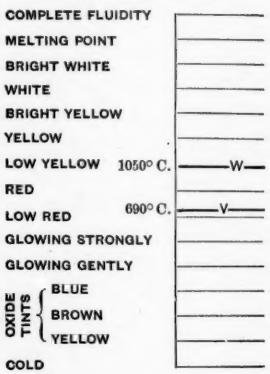
MOMENTARY DEPRESSION OF THE ELASTIC LIMIT OF STEEL AT TWO CRITICAL TEMPERATURES.

BY HENRY M. HOWE, A.M. (HARVARD), S.B.

THE phenomena which the present paper describes appear to be connected with certain very remarkable changes which iron, like the other strongly magnetic metals, nickel and cobalt, undergoes in heating and in cooling past certain critical temperatures or ranges of temperature, and of which many have until lately failed to attract the attention which they deserve.

The phenomena seem to be most marked at two temperatures, which have been named *V* and *W* respectively. *V* appears to lie at about 690°, or a dull red heat; *W*, at about 1,050° C., or at a low yellow heat. I have suggested grouping the phenomena tentatively according to the point at which they appear most markedly during *rising* temperature, into the *V* group and the *W* group.

FIG. 1. Position of *V* and *W*.



The *V* group includes, during *heating*, a sudden absorption of heat with corresponding fall of temperature and contraction, the emission of a crackling sound, the loss of the magnetic properties, a very marked change in the thermo-electric power, and a sudden enormous rise in specific heat, which, according to Pionchon, is nearly twice as great at 720° C. as at 660°.

The *W* group includes an absorption of heat, a complete and extraordinary change in the fracture, and in the micro-structure as revealed by the study of polished and of polished and etched sections; the sudden acquisition of the hardening power, *i.e.* the power of being rendered harder, and of acquiring coercive force or magnetic retentiveness, on sudden cooling; a change in the condition of the carbon which the metal contains; the union or welding of closely fitting surfaces, though *W* is

far below the true welding point of the metal; and the temporary depression of the elastic limit.

While certain of the phenomena which occur at *V* have been shown to be simultaneous, and while the same is true of some of those occurring at *W*, yet, partly owing to lack of co-operation among observers and partly to the difficulty of measuring high temperatures, we cannot yet say with confidence that all the members of each group occur simultaneously.

During cooling the counterparts or reversals of most if not all of the phenomena of the *W* group occur most markedly at *V*. Here occurs the most marked loss of hardening power, the most rapid change of carbon condition and of fracture; and here we find a most extraordinary evolution of heat and light, marked expansion, and the temporary depression of the elastic limit.

At least one member of each group is found in perfectly carbonless iron; but the intensity of most, and perhaps all, of the phenomena increases very greatly with the proportion of carbon present. Thus, when carbonless iron, reduced by hydrogen from pure ferric oxide, is heated, a decided absorption of heat occurs both at *V* and at *W*. On the other hand, though carbonless iron is not materially harder after sudden than after slow cooling from *W* or from higher temperatures, highly carburetted steel, while very easily filed and fairly ductile when slowly cooled, if suddenly cooled from *W* or from above *W*, is harder than glass and about as brittle. Further, while a slight quantity of heat is evolved when iron containing but little carbon is cooled from above *W* past *V*, when highly carburetted steel is thus cooled, so much heat is evolved as the temperature sinks past *V* that the cooling is arrested and the metal brightens visibly. The evolution of light in this case is so marked that even the untrained eye detects it readily, while watching in a dark room the cooling of a steel bar which has been highly heated at one end. It thus seems as if the change in the condition of carbon, while precipitated by some allotropic, molecular, or crystalline change in the iron, very greatly intensifies the phenomena resulting from this change, and gives rise to what are practically new ones, since not more than their germ, if even that, occurs in carbonless iron.

Of the phenomena which occur at *V* and *W*, some have been directly observed as these temperatures are passed. Among these are the thermal, magnetic and thermo-electric ones, and the temporary depression of the elastic limit. Others are inferred from a comparison of the properties of similar pieces of steel suddenly cooled from different temperatures. Thus, if steel be suddenly cooled from below *W*, its properties

are nearly the same as when it is slowly cooled; while if it be suddenly cooled from *W* or from slightly above *W*, we find the glass hardness and brittleness already noted, where we had relative softness and great toughness, *i.e.* capacity for great permanent distortion without rupture: we find a new condition of carbon; lower density; magnetic retentiveness which we did not have before; a porcelanic where we had a relatively coarsely crystalline fracture; and under the microscope a homogeneous, quasi-obsidian-like where we had a composite porphyritic or granitic substance. In short, we have a new material so unlike the old, that mere physical examination would hardly suggest that one could be converted readily into the other. Now, we infer naturally that the change from one condition to the other occurred when the temperature rose slowly past *W*, and that the suddenness of cooling has prevented the change from being reversed during cooling.

In harmony with this inference is the greater evolution of heat in dissolving suddenly cooled than in dissolving slowly cooled steel in a calorimeter: this certainly goes to show that the heat evolution due to the change which occurs in slow cooling past *V* is prevented by sudden cooling, and hence that the change itself is prevented.

At the same time the violent residual stress induced by sudden cooling doubtless influences the properties of suddenly cooled steel.

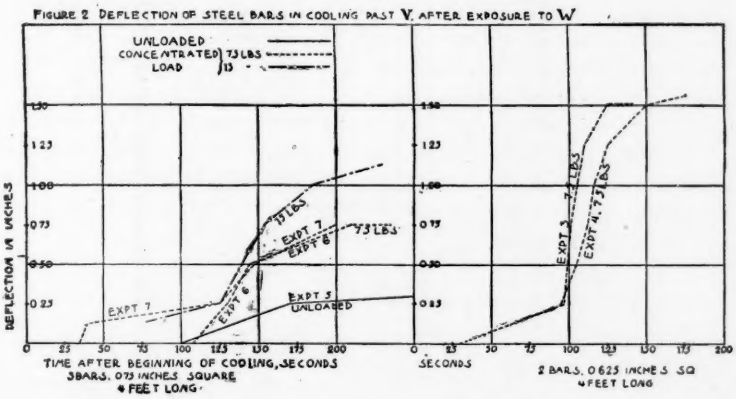
Certain of these phenomena have been discovered by a most talented engineer, Mr. John Coffin, of Johnstown, Pennsylvania; and it has been my good fortune to carry out with him the experiments which I will now describe.

Depression of the elastic limit on passing *W*. — Two straight steel bars, Nos. 2 and 3, containing 0.67 per cent of carbon, 0.625 inches square and four feet long, were heated near each other in a reverberatory furnace. 3 was supported at its ends only; 2 lay on the level hearth, and was thus supported over its whole length. 150 seconds after entering the furnace, and while passing a low yellow heat, 3 began to bend, and bent about one inch during the next 120 seconds; after this it ceased to bend, though the temperature was still rising. The deflection was measured roughly, by inserting gauges between the bar and a brick placed beneath it. Removed from the furnace 5.5 minutes later, and cooled slowly, the total deflection was found to be 1.05 inches, showing that practically all the bending had occurred during the two minutes while the bar was rising past some critical point, above which it ceased to bend. 2, apparently hotter than 3 had been while bending, was now placed on the same supports: no deflection could be detected.

Clearly the deflection was not due to temperature, as such, but to something which happened while the temperature was passing *W*.

Depression of the elastic limit while cooling from *W* past *V*. — Bar 3 had not bent perceptibly while its temperature was rising past *V*, so that this temperature, as such, does not affect the elastic limit abnormally.

As it was known that the elastic limit was temporarily depressed in falling from *W* past *V* (indeed, Mr. Coffin takes advantage of this in straightening railway axles, on a commercial scale), experiments were undertaken to test the effect of varying time and of varying load on the amount of permanent set in passing *V*. Their results are summed up in Table I. (p. 140).



Effect of varying time. — Bar 2 was left supported at its ends in the furnace, whose doors were raised slightly, so that it might cool slowly. After three hours it was so hot that to handle it was very painful. Its deflection was found to be practically the same as that of the exactly similar bar 4, cooling in the outer air on a warm summer's day, to wit, 0.47 inches *vs.* 0.44 inches (Expts. 1 and 2). Hence the deflection appears to be independent of the time occupied in passing *V*.

Effect of varying load. — Seven experiments were tried. In each the bar was heated well above *W*, while lying supported over its whole length, on the hearth of a reverberatory furnace. It was then removed, supported at its ends in the open air, allowed to cool by radiation, and the times of successive degrees of deflection noted. The deflection was observed by placing a vertical wooden scale beside the middle of the bar. In some cases a load, consisting of one or two bricks, was placed

Table I.

DEFLECTIONS OF STEEL BARS (FOUR FEET LONG, SUPPORTED AT BOTH ENDS AND LOADED IN THE MIDDLE) IN COOLING PAST *V* AFTER EXPOSURE TO *W*.

No. of Expt.	Description of Bar.			Conditions of Cooling.	Load in addit'n to weight of bar itself, lbs.	Bar plus load equivalent to a load concentrated in the centre, of	Cooling begins at	Load applied at	Maximum deflection.[1]	Successive Deflections[1] of									
	Number.	Size.	Per cent Carbon.							0.12 in	0.25 in	0.31 in	0.5 in	0.75 in	1.00 in	1.12 in	1.25 in	1.50 in	1.56
										Time at which these Deflections were observed.									
						lbs.	secs.	secs.	ins.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.	secs.
1	4	$\frac{5}{8}$" sq.	0.67	In air, slowly.	0.	3.3	0	...	0.44	...	...	...	...	...	...	...	...	...	...
2	2	"	"	In furnace, very slowly.	0.	3.3	0	...	0.47	...	...	...	...	...	...	...	...	...	...
3	1	"	"	In air, slowly.	7.5	10.8	0	25	1.50	...	97	...	...	102	105	...	110	125	...
4	4	"	"	In air, slowly.	7.5	10.8	0	20	1.56	...	95	...	105	111	116	...	125	150	175
The maximum deflection of a bar exactly similar to the four preceding, on heating to *W*, unloaded, was									1.06										
5	5	$\frac{3}{4}$" sq.	0.78	In air, slowly.	0.	4.7	0	...	0.31	135	170	250	...	...	...	...	...	...	...
6	5	"	"	In air, slowly.	7.5	12.2	0	25	0.75	...	130	...	145	210	...	...	...	...	...
7	6	"	"	In air, slowly.	7.5	12.2	0	30	0.75	39	125	...	148	200	...	...	...	...	...
8	7	"	"	In air, slowly.	15.	19.7	0	45	1.12	75	125	...	140	155	183	230	...	...	...

[1] These are the deflections in excess of the initial deflection which occurred immediately after applying the load.

on the middle of the bar. A certain deflection of course occurred on supporting and on loading the bar: the deflections given in Table I. are those in excess of this initial deflection. Duplicate experiments, 3 and 4, 6 and 7, gave results which agreed closely, considering the very crude arrangements.

It is striking that the deflections are proportional to the deflecting power of the different loads on cold beams.

In every case the deflection is very slight at first, then accelerates, then becomes slower. In case of the 0.75 inch bars the most rapid deflection occurs in each case between the 125th and the 160th seconds after removal from the furnace. The deflection curves of the two 0.625 inch bars are almost identical, the period of rapid deflection occurring between the 95th and the 125th seconds, or about thirty seconds earlier than in case of the thicker and more slowly cooling 0.75 inch bars.

The results are given exactly as observed, with no corrections for malobservation. I note but one apparent anomaly: the first noted deflection of Experiment 7 seems unduly early. As this was one of our first experiments, made before we had got into swing, I have little doubt that this is inaccurate.

The reversal of the curves and their final approach to the horizontal show that the weakening is temporary. To further test this, in one case (Expt. 5) a man's weight was placed on the middle of the bar for some seconds, beginning at 280 seconds after removal from the furnace, or within two minutes of the period of maximum deflection, and within 30 seconds of the time when the bar had ceased to bend visibly under its own weight. This produced no further permanent set measurable with our rough appliances. The bar thus stiffens with surprising rapidity.

That this deflection may be repeated with a given bar on again cooling from above *W* past *V* is shown by the fact that Experiment 5 was on the bar which had been used in Experiment 6, now placed convex side up. Its new permanent set was still proportional to the theoretical deflecting power of the load. So, too, the bar used in Experiment 4 had been used in Experiment 1, and was now loaded concave side up: its deflection was the same as that of a similar bar not previously treated.

To sum up: the permanent set which steel acquires under transverse stress at *V*, when cooling from *W* or above, appears to be independent of time, but directly proportional to the theoretical deflecting power of the load. Thus, in passing this critical point, the metal seems to offer to stress a resistance like in kind, but much feebler than that offered at the usual temperature.

These two depressions of the elastic limit occur while the state of the carbon is changing. There is a third condition which often arises, and under which the carbon of steel changes from one state to the other; to wit, when suddenly cooled steel is gently reheated or "tempered." Mr. Coffin has made the interesting discovery that during this change, also, the elastic limit of the metal is depressed temporarily.

For further information touching these remarkable changes in iron the following works may be consulted: —

Pionchon, Comptes Rendus, CII., pp. 675, 1454; CIII., p. 1122.

Gore, Phil. Mag., XXXVIII., p. 59; XL., p. 170.

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*SOME TESTS OF THE STRENGTH OF CAST IRON MADE IN THE LABORATORY OF APPLIED MECHANICS OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.**

By GAETANO LANZA, S.B., C. and M.E.

With Heywood Cochran, S.B., John K. Burgess, S.B., Maurice A. Vielé, S.B., Henry F. Eastman, S.B., and Wm. H. Gerrish, S.B.

The object of this paper is to give a brief account of several sets of tests upon the strength and other resisting properties of cast iron, carried on in the laboratory of Applied Mechanics of the Massachusetts Institute of Technology, of which the results are, it is believed, of sufficient practical value to render them worthy of record.

The experiments referred to have formed the subjects of three graduating theses, viz. : —

1st. An investigation upon the modulus of elasticity and some other properties of cast iron, by Heywood Cochran of the class of 1885.

2d. An investigation of the tensile and the transverse strengths of cast iron, and a comparison of their respective moduli of elasticity, by John K. Burgess and Maurice A. Vielé, of the class of 1886.

3d. Experiments upon pulleys, keys, and set screws, by Henry F. Eastman and William H. Gerrish, of the class of 1888.

The first portion of the work relates especially to the modulus of elasticity, and the limit of elasticity of common cast iron and of gun iron, both planed and unplaned.

The main portion of the experiments, however, are upon the transverse strength of cast iron when used in the forms of window lintels and of pulleys.

The reason for undertaking these tests was, that it is well known that the modulus of rupture of cast iron varies greatly, according to the form of the casting, and the manner of using it; and it was considered desirable to obtain some experimental results which should be applicable to the forms mentioned.

Some experiments were also made upon the strength of keys of cast iron, wrought iron, and steel, and upon the holding power of set screws, all of which are recorded here.

* Read before the American Society of Mechanical Engineers, October, 1888.

SUMMARY OF THE FIRST SET OF EXPERIMENTS — BY MR. HEYWOOD COCHRAN.

The object of the thesis was to determine the values of the modulus of elasticity, and of the limit of elasticity of certain kinds of common cast iron, and of gun iron, and the effect of re-testing the specimens.

The common iron consisted of a half-and-half mixture of Lake Superior magnetic and Harrington irons, the last being made from an English bog ore.

The gun iron consisted of a half-and-half mixture of Muirkirk, Md., and re-melted Salisbury irons.

The chemical analyses as far as determined were as follows: —

	Gun Iron. Per cent.	Common Iron. Per cent.
Total carbon	3.51	——
Graphite	2.80	——
Sulphur	0.133	0.173
Phosphorus	0.155	0.413
Silicon	1.140	1.89

The test specimens, all of which were cast at the South Boston Iron Foundry, were twenty-six inches long and square in section; those tested with the skin on being very nearly one inch square, and those tested with the skin removed being cast nearly one and one-quarter inches square, and afterwards planed down to one inch square.

All were of the same section throughout their entire length.

The tables of tests will now be given: —

Test No. 1.

UNPLANED COMMON IRON.

Gauged length, 13″.3125.
Area of section, 1.0455 square inches.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0004		18,148,370
1,500	0.0008		16,977,500
2,000	0.0012		16,608,450
500		0.0000	
2,500	0.0017		15,433,500
3,000	0.0023		14,148,000
3,500	0.0028		13,890,720
500		0.0002	
4,000	0.0032		13,926,800
4,500	0.0036		14,148,000
5,000	0.0042		13,807,000
500		0.0004	
5,500	0.0048		13,344,800
500		0.0004	
6,000	0.0052		13,533,540
500		0.0004	
6,500	0.0057		13,521,900
6,500	0.0056		
500		0.0004	
7,000	0.0061		13,568,140
500		0.0006	
7,500	0.0066		13,504,800
500		0.0008	

Tensile strength, 23,000 lbs. per square inch.

With a load of 11,000 lbs. the piece broke unexpectedly in the upper clamps, due to the fact that these clamps did not bind the piece as they should have done, but rather pinched it at its lower end. Then, too, the load was very suddenly applied. Upon re-testing, the piece broke with a load of 24,000 lbs., or 23,000 lbs. per sq. inch. A load of 6,500 lbs. was left on for seventeen hours and a half without producing any additional elongation. The position of the fracture was just outside the upper clamps.

Test No. 2.

UNPLANED COMMON IRON.

Gauged length, 13″.5938.
Area of section, 1.0754 square inches.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0004		18,058,140
1,500	0.0007		18,058,140
2,000	0.0011		17,237,310
2,500	0.0015		16,854,260
3,000	0.0020		16,206,000
3,500	0.0025		15,168,840
4,000	0.0030		14,997,430
4,500	0.0034		15,093,361
5,000	0.0039		14,585,430
500		0.0000	
5,500	0.0046		13,739,900
6,000	0.0050		13,904,800
6,500	0.0057		13,306,000
500		0.0003	
7,000	0.0063		13,146,330
7,500	0.0069		12,917,500
500		0.0005	
8,000	0.0075		12,640,700
500		0.0006	
8,500	0.0082		12,408,040
500		0.0005	
9,000	0.0095		
500		0.0009	

Tensile strength, 23,000 lbs. per square inch.

Test No. 3.

UNPLANED COMMON IRON.

Gauged length, 13″.4883.
Area of section, 1.0614 square inches.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0004		18,154,300
1,500	0.0008		16,398,300
2,000	0.0012		15,561,000
2,500	0.0017		14,950,600
3,000	0.0022		14,607,000
3,500	0.0026		14,523,460
4,000	0.0031		14,347,800
4,500	0.0037		13,926,600
5,000	0.0042		13,615,800
500		0.0001	
5,500	0.0050		12,771,900

At the end of the test a load of 9,000 lbs. was left upon the piece for seventy hours.

TEST NO. 4.

SAME SPECIMEN RE-TESTED.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0003		19,550,800
1,500	0.0007		18,154,300
2,000	0.0011		17,732,140
2,500	0.0015		17,528,300
3,000	0.0019		16,721,100
3,500	0.0023		16,575,700
4,000	0.0029		15,606,350
4,500	0.0035		14,734,000
5,000	0.0040		14,386,450
5,500	0.0048		13,237,530
500		0.0002	
6,000	0.0052		13,376,850
6,500	0.0058		13,146,240
500		0.0002	
7,000	0.0062		13,322,900
7,500	0.0066		13,478,200
500		0.0001	
8,000	0.0071		13,414,000
8,500	0.0076		13,376,900
500		0.0001	
9,000	0.0081		13,335,600
9,500	0.0086		13,299,100
500		0.0001	
10,000	0.0093		13,021,470
500		0.0002	
10,500	0.0100		12,771,900
500		0.0003	

The load of 5,500 lbs. was left upon the piece for two hours. At the end of this test a load of 12,000 lbs. was left upon the piece, this being above the limit of elasticity.

Test No. 5.

SAME PIECE RE-TESTED A SECOND TIME.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0004		14,950,630
1,500	0.0009		14,950,630
2,000	0.0013		14,950,630
2,500	0.0017		14,734,000
3,000	0.0022		14,606,900
3,500	0.0027		14,386,450
4,000	0.0032		14,120,030
4,500	0.0037		13,926,640
5,000	0.0042		13,779,800
5,500	0.0047		13,664,540
6,000	0.0052		13,571,700
6,500	0.0057		13,376,900
7,000	0.0062		13,322,900
7,500	0.0067		13,227,670
8,000	0.0073		13,146,230
8,500	0.0078		12,992,535
9,000	0.0084		12,859,320
9,500	0.0090		12,708,000
10,000	0.0095		12,708,000
10,500	0.0101		12,613,430
11,000	0.0107		12,499,700
500		0.0003	
11,500	0.0111		12,593,540
12,000	0.0117		12,490,800
12,500	0.0124		12,298,000
500		0.0007	
13,000	0.0130		12,266,430
500		0.0009	

Tensile strength, 20,200 lbs. per square inch.

TEST No. 6.

UNPLANED GUN IRON.

Gauged length, 13″.5625.
Area of section, 1.0506 square inch.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0003		21,505,580
1,500	0.0007		18,441,850
2,000	0.0011		18,441,850
2,500	0.0015		17,805,920
3,000	0.0019		17,445,000
3,500	0.0023		17,212,400
4,000	0.0027		17,050,000
4,500	0.0031		16,930,200
5,000	0.0036		16,363,900
500		0.0001	
5,500	0.0041		15,937,400
6,000	0.0046		15,435,000
6,500	0.0050		15,491,150
7,000	0.0055		15,256,440
500		0.0005	
7,500	0.0060		15,187,400
500		0.0005	
8,000	0.0063		15,368,480
500		0.0005	
8,500	0.0068		15,192,300
9,000	0.0074		14,929,830

Tensile strength, 17,990 lbs. per square inch.

The piece broke first with a load of 18,900 lbs., exhibiting a bad flaw, and then, upon being re-tested broke at 28,450 lbs., or about 27,000 lbs. per square inch.

Test No. 7.

UNPLANED GUN IRON.

Gauged length, 13."3906.
Area of section, 1.0630 square inch.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0003		22,903,620
1,500	0.0005		23,994,300
2,000	0.0008		22,903,620
2,500	0.0012		21,907,800
3,000	0.0016		20,316,700
3,500	0.0020		19,380,000
4,000	0.0024		18,761,470
4,500	0.0027		18,662,200
5,000	0.0031		18,286,000
5,500	0.0035		18,125,160
6,000	0.0039		17,995,300
6,500	0.0043		17,680,000
7,000	0.0047		17,421,370
7,500	0.0051		17,205,540
8,000	0.0055		17,177,700
500		0.0000	
8,500	0.0059		17,080,670
9,000	0.0064		16,862,100
500		0.0000	
9,500	0.0068		16,672,500
10,000	0.0072		16,621,370
500		0.0002	
10,500	0.0078		16,254,180
11,000	0.0082		16,130,300
500		0.0003	
11,500	0.0087		16,019,300
500		0.0004	
12,000	0.0092		15,746,240
500		0.0005	
12,500	0.0098		15,504,000
500		0.0008	
13,000	0.0104		15,213,760
500		0.0009	

A load of 13,250 lbs. remained upon this piece for seventeen hours, this load being just above the elastic limit.

TEST NO. 8.

SAME SPECIMEN RE-TESTED.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0003		20,995,000
1,500	0.0006		20,995,000
2,000	0.0009		20,427,550
2,500	0.0013		19,760,000
3,000	0.0017		19,076,300
3,500	0.0021		18,212,500
4,000	0.0025		17,995,700
4,500	0.0028		17,836,440
5,000	0.0032		17,714,500
5,500	0.0036		17,495,820
6,000	0.0040		17,429,800
6,500	0.0044		17,275,870
7,000	0.0048		17,147,750
7,500	0.0052		16,876,350
8,000	0.0056		16,796,000
500		0.0000	
8,500	0.0061		16,588,250
9,000	0.0065		16,536,580
9,500	0.0069		16,490,600
10,000	0.0073		16,449,700
500		0.0002	
10,500	0.0077		16,306,800
11,000	0.0081		16,279,200
500		0.0002	
11,500	0.0085		16,254,180
12,000	0.0089		16,231,410
12,500	0.0093		16,210,600
13,000	0.0098		16,108,680
500		0.0002	
13,500	0.0102		16,094,430
14,000	0.0108		15,782,750
14,500	0.0112		15,711,200
500		0.0003	
15,000	0.0118		15,446,600
500		0.0005	
16,000	0.0130		

A load of 16,000 lbs. was left upon the piece for 22 hours.

Test No. 9.

SAME SPECIMEN RE-TESTED A SECOND TIME.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0003		19,380,000
1,500	0.0006		20,156,200
2,000	0.0009		20,427,550
2,500	0.0012		20,995,000
3,000	0.0016		20,317,700
3,500	0.0019		19,631,700
4,000	0.0023		19,169,300
4,500	0.0028		18,323,000
5,000	0.0032		17,995,700
5,500	0.0035		17,868,100
6,000	0.0039		17,995,700
6,500	0.0043		17,784,000
7,000	0.0047		17,703,890
7,500	0.0050		17,548,000
8,000	0.0054		17,495,820
8,500	0.0058		17,450,400
9,000	0.0062		17,420,450
9,500	0.0065		17,375,160
10,000	0.0071		16,974,670
10,500	0.0075		16,796,000
11,000	0.0080		16,637,530
11,500	0.0084		16,545,300
500		0.0000	16,415,340
12,000	0.0088		
12,500	0.0093		16,342,042
13,000	0.0097		16,233,240
13,500	0.0102		16,134,100
14,000	0.0106		16,043,300
500		0.0002	
14,500	0.0111		15,960,000
15,000	0.0115		15,883,000
15,500	0.0120		15,779,100
16,000	0.0125		15,620,300
500		0.0001	
16,500	0.0130		15,504,000
500		0.0001	

Tensile strength, 25,494 lbs. per square inch.

This piece broke first with a load of 27,100 lbs., exhibiting a flaw; upon being re-tested it broke with 30,450 lbs., or 28,750 lbs. per square inch.

Test No. 10.

UNPLANED GUN IRON.

Gauged length, 13″.4844.
Area of section, 1.0620 square inch.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0003		21,168,200
1,500	0.0006		22,088,600
2,000	0.0009		21,773,000
2,500	0.0012		21,618,630
3,000	0.0015		20,821,220
3,500	0.0019		20,054,100
4,000	0.0023		19,757,020
4,500	0.0027		18,816,200
5,000	0.0031		18,586,800
5,500	0.0035		18,184,200
6,000	0.0040		17,684,900
6,500	0.0044		17,518,545
7,000	0.0048		17,380,200
7,500	0.0052		17,180,000
500		0.0001	
8,000	0.0057		16.859,700
8,500	0.0061		16,657,000
500		0.0002	

Tensile strength, 21,657 lbs. per square inch.

The piece broke first at 23,000 lbs., exhibiting a flaw, and on being re-tested, it broke at 30,550 lbs., or 28,775 lbs. per square inch.

Test No. 11.

PLANED COMMON IRON.

Gauged length, 13″.5274.
Area of section, 0.9937 square inch.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0004		19,447,200
1,500	0.0009		16,015,440
500		0.0000	
2,000	0.0014		14,329,500
2,500	0.0021		12,964,800
3,000	0.0028		12,154,500
500		0.0002	
3,500	0.0032		12,762,200
4,000	0.0040		12,062,200
500*		0.0004	
4,500	0.0044		12,446,200
500		0.0015	
5,000	0.0049		12,501,750
500		0.0015	
5,500	0.0056		12,154,500
500		0.0015	
6,000	0.0064		11,698,700
500		0.0018	
6,500	0.0068		12,100,000
500		0.0019	

A load of 10,000 lbs. was left upon this piece over night.

* Tightened the clamps.

Test No. 12.

SAME SPECIMEN RE-TESTED.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0004		18,150,700
1,500	0.0010		14,329,500
2,000	0.0016		13,173,900
2,500	0.0021		12,812,300
500		−0.0001	
3,000	0.0029		11,941,250
3,500	0.0034		12,039,200
4,000	0.0039		12,216,800
500		0.0000	
4,500	0.0045		12,236,430
500		0.0000	
5,000	0.0051		12,070,700
500		0.0001	
5,500	0.0059		11,635,100
500		0.0001	
6,000	0.0064		11,790,600
500		0.0001	
6,500	0.0071		11,585,600
500		0.0001	
7,000	0.0078		11,344,200
500		0.0001	
7,500	0.0085		11,243,800
500		0.0001	
8,000	0.0093		11,037,600
500		0.0001	
8,500	0.0098		11,169,680
500		0.0001	
9,000	0.0106		10,890,430
500		0.0003	
9,500	0.0112		10,939,000
500		0.0003	
10,000	0.0121		10,732,250
500		0.0004	
10,500	0.0129		10,593,800
500		0.0006	
11,000	0.0139		10,320,350
500		0.0006	
11,500	0.0148		10,100,730
500		0.0009	
12,000	0.0157		9,971,330
500		0.0013	

A load of 14,000 lbs. was left upon this piece over night.

Test No. 13.

SAME SPECIMEN RE-TESTED A SECOND TIME.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0005		13,613,040
1,500	0.0011		12,964,800
2,000	0.0017		12,375,500
2,500	0.0024		11,585,540
3,000	0.0029		11,635,100
3,500	0.0035		11,585,540
4,000	0.0042		11,480,900
4,500	0.0048		11,463,600
5,000	0.0054		11,344,200
5,500	0.0061		11,250,440
6,000	0.0067		11,216,730
6,500	0.0075		10,900,460
7,000	0.0082		10,790,810
7,500	0.0091		10,529,420
8,000	0.0097		10,498,500
500		0.0001	
8,500	0.0105		10,421,500
9,000	0.0112		10,377,650
9,500	0.0119		10,274,000
10,000	0.0128		10,151,000
500		0.0002	
10,500	0.0135		10,121,200
11,000	0.0143		10,030,500
500		0.0002	
11,500	0.0151		9,936,500
12,000	0.0160		9,789,680
500		0.0003	
12,500	0.0170		9,637,550
500		0.0004	
13,000	0.0178		9,586,642
500		0.0004	
13,500	0.0185		9,591,840
500		0.0005	
14,000	0.0192		9,589,220
500		0.0006	
14,500	0.0206		9,270,480
500		0.0010	

Tensile strength, 20,800 lbs. per square inch.

TEST NO. 14.

PLANED COMMON IRON.

Gauged length, 13'.461.

Area of section, 0.9852 square inch.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0004		19,518,890
1,500	0.0008		18,217,600
2,000	0.0012		17,071,150
2,500	0.0018		15,615,100
3,000	0.0024		14,232,000
3,500	0.0030		13,663,200
500		0.0000	
4,000	0.0037		12,837,900
4,500	0.0043		12,710,000
500		0.0002	
5,000	0.0048		12,742,900
500		0.0002	
5,500	0.0054		12,769,360
500		0.0004	
6,000	0.0060		12,629,900
500		0.0009	
6,500	0.0068		12,145,100
500		0.0010	
7,000	0.0075		11,802,000
500		0.0011	
7,500	0.0083		11,628,300
500		0.0013	
8,000	0.0089		11,481,700
500		0.0014	
8,500	0.0096		11,386,000
500		0.0018	
9,000	0.0102		11,430,200
500		0.0019	
9,500	0.0115		11,028,600
500		0.0021	
10,000	0.0122		10,661,250
500		0.0923	

Test No. 15.

SAME SPECIMEN RE-TESTED.

Loads, Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0004		18,217,400
1,500	0.0008		17,630,000
2,000	0.0013		16,777,700
2,500	0.0018		14,973,400
3,000	0.0024		14,085,465
3,500	0.0031		13,439,240
4,000	0.0036		13,101,260
4,500	0.0042		12,935,590
5,000	0.0048		12,809,270
500		−0.0001	
5,500	0.0055		12,421,100
6,000	0.0061		12,319,300
500		−0.0001	
6,500	0.0067		12,190,230
7,000	0.0074		12,083,110
7,500	0.0081		11,855,200
8,000	0.0088		11,600,850
500		−0.0001	
8,500	0.0096		11,356,700
9,000	0.0103		11,248,170
9,500	0.0110		11,153,450
500		0.0000	
10,000	0.0119		10,930,510
500		0.0001	
10,500	0.0129		10,612,200
500		0.0003	
11,000	0.0139		10,321,150
500		0.0005	
11,500	0.0148		10,138,000
500		0.0007	
12,000	0.0162		9,714,190

TEST NO. 16.

SAME SPECIMENS RE-TESTED A SECOND TIME.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0005		13,663,220
1,500	0.0012		11,881,090
2,000	0.0017		12,421,100
2,500	0.0023		12,145,100
3,000	0.0028		12,191,340
3,500	0.0035		11,881,090
4,000	0.0043		11,252,060
4,500	0.0050		10,930,600
5,000	0.0056		10,979,370
500		0.0002	
5,500	0.0063		10,930,600
6,000	0.0070		10,812,620
6,500	0.0077		10,646,700
7,000	0.0084		10,572,730
500		0.0001	
7,500	0.0090		10,626,950
8,000	0.0097		10,564,340
8,500	0.0104		10,510,160
9,000	0.0111		10,486,400
500		0.0002	
9,500	0.0118		10,465,440
10,000	0.0125		10,425,750
10,500	0.0132		10,331,350
11,000	0.0140		10,247,410
500		0.0002	
11,500	0.0149		10,086,900
12,000	0.0158		9,976,310
500		0.0003	
12,500	0.0164		10,012,735
500		0.0002	
13,000	0.0174		9,843,800
500		0.0002	
13,500	0.0182		9,759,440
500		0.0002	
14,000	0.0191		9,682,590
500		0.0005	
14,500	0.0202		9,430,500
500		0.0010	

Tensile strength, 20,300 lbs. per square inch.

Test No. 17.

PLANED COMMON IRON.

Gauged length, 13″.582.
Area of section, 0.996 square inches.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0005		15,151,720
1,500	0.0009		16,054,000
2,000	0.0014		14,610,600
2,500	0.0019		14,354,260
3,000	0.0025		13,636,550
3,500	0.0032		12,987,200
4,000	0.0037		12,899,440
500		0.0000	
4,500	0.0044		12,114,840
5,000	0.0051		11,973,550
5,500	0.0059		11,605,570
6,000	0.0066		11,363,800
500		0.0006	
6,500	0.0071		11,605,570
7,000	0.0078		11,437,100
500		0.0008	
7,500	0.0084		11,429,200
500		0.0011	
8,000	0.0091		11,238,900
500		0.0014	
8,500	0.0102		10,748,000
500		0.0017	
9,000	0.0109		10,634,000
500		0.0019	
9,500	0.0116		10,580,080
500		0.0022	
10,000	0.0123		10,575,300

Test No. 18.

THE SAME RE-TESTED.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0005		15,151,720
1,500	0.0009		15,151,720
2,000	0.0014		15,151,720
2,500	0.0019		14,742,215
3,000	0.0024		14,204,740
3,500	0.0030		13,867,700
4,000	0.0036		13,444,480
4,500	0.0042		13,143,660
5,000	0.0049		12,523,360
500		−0.0002	
5,500	0.0056		12,285,200
6,000	0.0063		12,000,170
500		−0.0002	
6,500	0.0070		11,688,500
7,000	0.0077		11,586,600
500		−0.0002	
7,500	0.0084		11,431,840
8,000	0.0092		11,177,500
500		−0.0003	
8,500	0.0099		11,019,430
500		−0.0002	
9,000	0.0106		10,935,000
500		−0.0002	
9,500	0.0114		10,813,120
500		−0.0001	
10,000	0.0121		10,706,130
500		0.0001	
10,500	0.0129		10,611,860
500		0.0002	
11,000	0.0139		10,301,000
500		0.0005	
11,500	0.0150		10,000,000
500		0.0009	
12,000	0.0162		9,710,230

Test No. 19.

SAME SPECIMEN RE-TESTED A SECOND TIME.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0006		13,396,900
1,500	0.0011		12,987,200
2,000	0.0017		12,396,900
2,500	0.0023		12,121,380
3,000	0.0029		11,755,600
3,500	0.0035		11,688,500
4,000	0.0041		11,640,900
4,500	0.0048		11,483,400
5,000	0.0054		11,363,800
5,500	0.0061		11,288,520
6,000	0.0068		11,029,560
6,500	0.0076		10,837,000
7,000	0.0083		10,679,200
7,500	0.0091		10,587,600
8,000	0.0098		10,424,120
500		0.0000	
8,500	0.0105		10,437,050
9,000	0.0114		10,212,400
500		0.0000	
9,500	0.0121		10,198,700
10,000	0.0129		10,042,400
500		0.0001	
10,500	0.0138		9,917,490
500		0.0001	
11,000	0.0146		9,840,810
500		0.0001	
11,500	0.0153		9,836,200
500		0.0002	
12,000	0.0160		9,832,000
500		0.0001	
12,500	0.0171		9,597,570
500		0.0001	
13,000	0.0178		9,576,230
500		0.0003	
13,500	0.0189		9,379,640
500		0.0004	
14,000	0.0198		9,279,650

Tensile strength, 20,450 lbs. per square inch.

TEST NO. 20.

PLANED GUN IRON.

Gauged length, 13″.2774.
Area of section, 1.0028 square inch.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0004		18,879,100
1,500	0.0007		18,879,100
2,000	0.0011		18,055,000
2,500	0.0015		17,603,000
3,000	0.0019		17,195,100
3,500	0.0024		16,724,600
4,000	0.0028		16,403,950
4,500	0.0033		16,171,410
5,000	0.0038		15,888,400
500		0.0002	
5,500	0.0041		16,048,900
6,000	0.0046		16,004,800
6,500	0.0050		15,888,400
7,000	0.0055		15,791,200
500		0.0002	
7,500	0.0059		15,642,550
500		0.0003	
8,000	0.0066		15,160,680
8,500	0.0070		15,240,680
500		0.0007	
9,000	0.0073		15,523,100
9,500	0.0077		15,576,800
500		0.0008	
10,000	0.0081		15,529,800
500		0.0009	
10,500	0.0086		15,395,800
500		0.0009	
11,000	0.0091		15,277,300
500		0.0010	
11,500	0.0097		15,092,600
500		0.0011	
12,000	0.0102		15,075,600
500		0.0014	

Tensile strength, 29,500 lbs. per square inch.

Test No. 21.

SAME SPECIMEN RE-TESTED.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0004		17,653,780
1,500	0.0008		17,653,780
2,000	0.0012		17,270,000
2,500	0.0016		17,084,320
3,000	0.0020		16,974,800
3,500	0.0024		16,550,400
4,000	0.0029		16,260,000
4,500	0.0033		16,295,800
5,000	0.0037		16,323,700
5,500	0.0041		16,146,740
500		0.0000	
6,000	0.0046		16,004,800
6,500	0.0050		15,888,400
7,000	0.0055		15,792,600
7,500	0.0059		15,708,860
500		0.0001	
8,000	0.0064		15,576,850
8,500	0.0069		15,463,150
9,000	0.0073		15,469,800
500		0.0001	
9,500	0.0078		15,277,660
10,000	0.0083		15,246,440
10,500	0.0087		15,218,770
500		0.0002	
11,000	0.0092		15,111,200
11,500	0.0097		15,014,800
500		0.0002	
12,000	0.0102		14,927,800
12,500	0.0107		14,849,000
500		0.0004	
13,000	0.0113		14,711,480
13,500	0.0117		14,711,480
500		0.0004	
14,000	0.0122		14,711,480
14,500	0.0128		14,481,600
500		0.0006	

TEST NO. 22.

SAME SPECIMEN RE-TESTED A SECOND TIME.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0 0004		17,653,900
1,500	0.0008		17,653,900
2,000	0.0011		17,653,900
2,500	0.0016		17,084,300
3,000	0.0020		16,759,900
3,500	0.0024		16,550,410
4,000	0.0028		16,404,000
4,500	0.0033		16,295,800
5,000	0.0037		15,995,000
5,500	0.0042		15,856,700
6,000	0.0046		15,827,200
6,500	0.0051		15,653,600
7,000	0.0056		15,506,700
500		0.0005	
7,500	0.0061		15,319,400
8,000	0.0065		15,395,700
8,500	0.0068		15,576,890
9,000	0.0072		15,740,300
9,500	0.0076		15,783,170
10,000	0.0080		15,722,900
500		0.0002	
10,500	0.0088		15,131,800
11,000	0.0093		15,029,600
11,500	0.0098		14,937,800
12,000	0.0103		14,855,000
500		0.0001	
12,500	0.0109		14,644,000
13,000	0.0113		14,646,720
13,500	0.0118		14,586,800
500		0.0002	
14,000	0.0123		14,532,090
14,500	0.0128		14,152,000
500		0.0002	
15,000	0.0134		14,327,220
500		0.0002	
15,500	0.0140		14,160,780
500		0.0003	
16,000	0.0146		14,056,500
500		0.0004	
16,500	0.0152		13,937,200
500		0.0006	
17,000	0.0158		13,870,800
500		0.0009	

Tensile strength, 29,500 lbs. per square inch.

Test No. 23.

PLANED GUN IRON.

Gauged length, 13″.508.
Area of section, 0.9930 square inches.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0003		20,927,000
1,500	0.0007		20,927,000
2,000	0.0010		20,404,850
2,500	0.0014		19,786,500
3,000	0.0018		19,433,200
3,500	0.0021		19,204,560
4,000	0.0025		18,856,000
4,500	0.0029		18,602,700
5,000	0.0034		18,273,000
500		−0.0001	
5,500	0.0039		17,440,000
6,000	0.0044		17,199,500
6,500	0.0048		17,004,000
7,000	0.0053		16,684,000
500		0.0000	
7,500	0.0057		16,632,800
8,000	0.0062		16,455,550
8,500	0.0067		16,242,650
500		0.0002	
9,000	0.0071		16,228,400
9,500	0.0077		16,003,800
500		0.0005	
10,000	0.0081		16,053,500
500		0.0006	
10,500	0.0087		15,726,270
500		0.0008	
11,000	0.0090		15,870,430
500		0.0010	
11,500	0.0095		15,834,450
500		0.0013	
12,000	0.0099		15,881,940

TEST NO. 24.

SAME SPECIMEN RE-TESTED.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0004		19,433,200
1,500	0.0007		18,763,070
2,000	0.0011		18,549,900
2,500	0.0016		17,552,550
500		0.0001	
3,000	0.0020		17,219,270
3,500	0.0024		17,004,030
4,000	0.0029		16,705,700
4,500	0.0033		16,488,760
5,000	0.0038		16,323,860
5,500	0.0042		16,194,300
6,000	0.0047		16,089,900
6,500	0.0051		16,003,800
7,000	0.0056		15,931,740
7,500	0.0060		15,870,430
8,000	0.0065		15,817,700
500		0.0001	
8,500	0.0070		15,858,400
9,000	0.0074		15,625,330
9,500	0.0079		15,596,053
10,000	0.0083		15,569,950
500		0.0002	
10,500	0.0088		15,546,540
11,000	0.0092		15,525,420
11,500	0.0097		15,426,340
500		0.0004	
12,000	0.0101		15,527,250
500		0.0004	
12,500	0.0106		15,472,900
500		0.0005	
13,000	0.0110		15,459,200
500		0.0005	
13,500	0.0116		15,311,000
500		0.0006	
14,000	0.0121		15,240,130

Test No. 25.

SAME SPECIMEN RE-TESTED A SECOND TIME.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0004		18,137,700
1,500	0.0008		18,137,700
2,000	0.0012		17,743,340
2,500	0.0016		17,552,550
3,000	0.0020		17,440,030
3,500	0.0023		17,740,340
4,000	0.0027		17,633,800
4,500	0.0031		17,552,550
5,000	0.0035		17,489,900
5,500	0.0040		17,219,280
6,000	0.0044		17,004,030
6,500	0.0049		16,828,740
7,000	0.0053		16,682,200
7,500	0.0058		16,556,560
8,000	0.0062		16,455,500
8,500	0.0067		16,364,800
9,000	0.0071		16,285,550
9,500	0.0076		16,215,260
10,000	0.0080		16,153,800
500		0.0000	
10,500	0.0085		16,051,000
11,000	0.0089		15,959,100
11,500	0.0094		15,876,440
12,000	0.0099		15,801,730
500		0.0000	
12,500	0.0105		15,620,900
13,000	0.0112		15,250,250
500		0.0000	
13,500	0.0118		14,990,060
14,000	0.0123		14,930,375
500		0.0000	
14,500	0.0128		14,849,530
500		0.0001	
15,000	0.0133		14,886,550
500		0.0001	
15,500	0.0138		14,839,900
500		0.0002	
16,000	0.0143		14,796,500
500		0.0003	
16,500	0.0149		14,583,025
500		0.0006	
17,000	0.0156		14,388,000

Tensile strength, 31,000 lbs. per square inch.

TEST NO. 26.

PLANED GUN IRON.

Gauged length, 13'.5274.
Area of section, 0.99 square inch.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0003		21,021,600
1,500	0.0007		21,021,600
2,000	0.0010		21,021,600
2,500	0.0013		20,625,000
3,000	0.0017		20,094,200
3,500	0.0021		19,520,050
4,000	0.0025		19,129,700
4,500	0.0029		18,847,000
5,000	0.0034		18,218,320
500		−0.0001	
5,500	0.0039		17,631,020
6,000	0.0044		17,276,400
6,500	0.0048		17,080,000
7,000	0.0053		16,917,400
7,500	0.0057		16,780,400
500		0.0002	
8,000	0.0062		16,529,100
8,500	0.0067		16,315,300
500		0.0004	
9,000	0.0071		16,301,000
9,500	0.0077		16,075,320
500		0.0005	
10,000	0.0082		15,927,400
500		0.0006	
10,500	0.0086		15,888,420
500		0.0008	
11,000	0.0093		15,510,530
500		0.0009	
11,500	0.0098		15,415,850
500		0.0011	
12,000	0.0101		15,558,060

Test No. 27.

SAME SPECIMEN RE-TESTED.

Loads Applied.	Elongation, Inches.	Sets, Inches.	E.
500	0.0000		
1,000	0.0004		19,520,060
1,500	0.0007		19,520,060
2,000	0.0011		19,066,100
2,500	0.0015		18,846,950
3,000	0.0019		18,218,720
3,500	0.0023		17,882,670
4,000	0.0028		17,390,600
4,500	0.0032		17,351,170
5,000	0.0036		17,320,600
5,500	0.0040		17,186,710
500		0.0001	
6,000	0.0044		17,177,500
6,500	0.0049		16,606,935
7,000	0.0054		16,447,460
7,500	0.0059		16,211,940
8,000	0.0064		16,059,445
500		0.0002	
8,500	0.0070		15,728,400
9,000	0.0074		15,695,200
9,500	0.0078		15,766,200
500		0.0002	
10,000	0.0083		15,592,600
10,500	0.0088		15,616,050
11,000	0.0093		15,510,540
500		0.0002	
11,500	0.0097		15,455,475
12,000	0.0102		15,367,850
500		0.0004	
12,500	0.0106		15,468,700
500		0.0004	
13,000	0.0111		15,387,440
500		0.0004	
13,500	0.0116		15,280,340
500		0.0004	
14,000	0.0122		15,182,270
500		0.0005	

Tensile strength, 31,000 lbs. per square inch.

TEST NO. 28.

SAME SPECIMEN RE-TESTED A SECOND TIME.

Loads Applied.	Elongation, Inches	Sets, Inches.	E.
500	0.0000		
1,000	0.0004		18,176,400
1,500	0.0008		18,176,400
2,000	0.0012		17,781,700
2,500	0.0016		17,714,500
3,000	0.0020		16,830,400
3,500	0.0025		16,524,400
4,000	0.0029		16,312,530
4,500	0.0034		16,120,000
5,000	0.0038		16,038,370
5,500	0.0043		15,907,900
6,000	0.0047		15,868,650
6,500	0.0052		15,806,000
7,000	0.0056		15,753,250
7,500	0.0061		15,708,360
8,000	0.0066		15,609,500
8,500	0.0070		15,524,700
9,000	0.0075		15,450,300
9,500	0.0080		15,336,700
10,000	0.0086		14,999,200
500		0.0002	
10,500	0.0091		14,980,900
11,000	0.0095		15,067,620
11,500	0.0100		15,071,200
12,000	0.0104		15,074,530
12,500	0.0109		15,008,380
13,000	0.0114		15,013,900
13,500	0.0119		14,955,600
14,000	0.0124		14,914,100
14,500	0.0129		14,852,750
500		0.0003	
15,000	0.0134		14,724,250
15,500	0.0140		14,580,330
16,000	0.0146		14,448,250
500		0.0003	
16,500	0.0152		14,346,820
17,000	0.0158		14,259,150
500		0.0005	

Tensile strength, 31,000 lbs. per square inch.

From these tests Mr. Cochran obtains the following as average values for the specimens tested, viz. : —

For tensile strength : —

Unplaned common	22,066
Planed common	20,520
Unplaned gun	21,714
Planed gun	30,500

For limit of elasticity : —

Unplaned common	6,500
Planed common	5,833
Unplaned gun	11,000
Planed gun	8,500

For modulus of elasticity at assumed elastic limit : —

Unplaned common	13,194,233
Planed common	11,943,953
Unplaned gun	16,130,300
Planed gun	15,932,880

Colonel Rosset of the Turin arsenal gave for gun iron, as average limit of elasticity, 9,800, and as average modulus of elasticity, 16,263,300.

Mr. Cochran attributes the apparent anomaly in the case of gun iron, whose average tensile strength is less in the unplaned than in the planed, to the presence of surface flaws in the unplaned gun.

Mr. Cochran draws from his tests the following conclusions, viz. : —

1°. Planed pieces stretch more than unplaned.

2°. The moduli of planed are higher than those of unplaned pieces.

3°. Common iron stretches from $\frac{1}{3}$ to $\frac{1}{2}$ more than gun iron.

4°. The elastic limit for unplaned is higher than that for planed.

5°. The effect of re-testing is to lower the modulus of elasticity, to raise the elastic limit, to make the stretch more nearly equal on the two sides, and probably to lower the tensile strength.

Summary of the Experiments of Messrs. Burgess and Vielé.

The object of this investigation was to determine the transverse strength of cast iron in the form of window lintels, and also the deflections under moderate loads, and from the latter to deduce the modulus of elasticity of the cast iron, and to compare it with the modulus of elasticity of the same iron, as determined from tensile experiments; also the tensile strength and limit of elasticity of specimens taken from different parts of the lintel were determined.

The iron used was of two qualities, marked *P* and *S* respectively; that marked *P* was composed or what was called at the foundry of L. M. Ham & Co., where the casting was done, No. 1 and No. 2 pig.

No. 1 pig was prepared by mixing the following ores: —

Neshannock from Pennsylvania	25.0 per cent.
Franklin from New York	37.5 per cent.
Crozen from Virginia	37.5 per cent.

No. 2 pig was made by mixing Franklin and Crozen in equal parts.

The chemical composition of *P* is as follows: —

Graphite	3.00
Combined carbon	0.56
Sulphur	0.53
Silicon	1.34
Phosphorus	1.13
Manganese	0.33
Iron by difference	93.11

The iron marked *S* was made of old scrap. Its chemical composition was as follows: —

Graphite	2.39
Combined carbon	0.85
Sulphur	0.07
Silicon	1.49
Phosphorus	1.12
Manganese	0.40
Iron by difference	93.68

The specimens for tension were 24 inches long, and about one inch square in section.

The transverse tests were made on window lintels of the following dimensions: —

	Inches.
Length	54.00
Breadth of flange	8.00
Height of web at the centre of lintel above flange	4.00
Height of web at edge of lintel above flange	2.50
Thickness of web and flange	0.75

The tensile specimens were cast at the same time, and from the same run as the lintels.

Besides this, one of each kind of window lintels was cut up into tensile specimens, and the specimens were so marked as to show from what part of the lintel they were cut.

The tables of tests will now be given, and the following explanation of the symbolism employed.

P and *S* are used, as already stated, to denote the quality of the iron.

A and *B* are used to denote respectively that the specimen was unplaned or planed.

1, 2, 3, etc., denote the number of the test made on that particular kind and condition.

I., II., III., denote that the piece has been taken from a lintel, and also from what part, as will easily be seen by the accompanying sketch (Fig. 31).

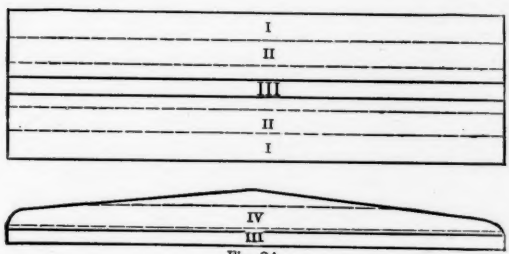


Fig. 31.

Thus *P. B.* 3 would signify that the specimen was of quality *P*, had been planed, and was the third test of this class.

On the other hand, *P. B.* 3 II. would signify in addition that it had been taken from a lintel, and was a piece of one of the strips marked II. in the sketch.

Loads Applied.	P. A. 1. Area = 1.0568 square inch.			S. A. 1. Area = 0.9683 square inch.			S. A. 2. Area = 1.0302 square inch.			P. A. 2. Area = 1.0323 square inch.			S. A. 3. Area = 1.02 square inch.			P. A. 3. Area = 1.027 square inch.		
	Loads per square inch.	Elongation, inches.	E.	Loads per square inch.	Elongation, inches.	E.	Loads per square inch.	Elongation, inches.	E.	Loads per square inch.	Elongation, inches.	E.	Loads per square inch.	Elongation, inches.	E.	Loads per square inch.	Elongation, inches.	E.
500	473	0.0000		516	0.0000		485	0.0000		484	0.0000		490	0.0000		487	0.0000	
1,000										969	0.0002	24,224,845				974	0.0003	16,228,496
1,500										1,453	0.0004	24,224,845				1,461	0.0008	12,982,798
2,000										1,937	0.0007	21,533,186				1,947	0.0012	13,291,913
2,500	2,365	0.0014	14,002,664	2,582	0.0011	18,777,052				2,422	0.0010	20,187,357	2,451	0.0011	17,825,311	2,434	0.0015	13,446,471
3,000							2,912	0.0010	24,267,133	2,906	0.0014	18,918,435				2,921	0.0018	14,002,876
3,500										3,390	0.0016	18,995,337				3,408	0.0022	13,987,420
4,000										3,875	0.0019	18,588,841				3,895	0.0026	13,534,789
4,500	4,257	0.0027	14,271,942	4,647	0.0022	18,777,052				4,359	0.0024	17,611,059	4,412	0.0022	18,249,723	4,382	0.0030	13,581,708
5,000										4,844	0.0028	17,000,099				4,869	0.0034	13,425,004
5,500							5,339	0.0024	21,121,393	5,328	0.0032	16,511,331				5,355	0.0037	13,705,353
6,000										5,812	0.0036	16,111,430				5,842	0.0040	13,442,958
6,500	6,150	0.0044	13,115,313	6,713	0.0034	18,504,922				6,297	0.0040	15,778,180	6,373	0.0033	17,849,914	6,329	0.0044	13,336,992
7,000										6,781	0.0045	15,309,852				6,816	0.0048	13,247,329
7,500										7,265	0.0049	14,985,353				7,303	0.0053	12,996,599
8,000							7,766	0.0039	19,299,667	7,750	0.0054	14,704,101				7,790	0.0057	12,941,587
8,500	8,042	0.0062	12,536,999	8,778	0.0047	17,850,759				8,234	0.0058	14,458,006	8,333	0.0048	17,309,004	8,276	0.0062	12,741,304
9,000										8,718	0.0063	14,240,805				8,763	0.0067	12,628,227
9,500										9,203	0.0068	13,988,034				9,250	0.0073	12,377,451
10,000										9,687	0.0072	13,818,482				9,735	0.0077	12,366,604
10,500	9,934	0.0080	11,889,057	10,843	0.0061	17,129,539	10,192	0.0054	18,519,273	10,171	0.0077	13,612,055	10,294	0.0062	16,461,582	10,224	0.0083	12,153,986
11,000										10,656	0.0083	13,383,348				10,711	0.0087	12,154,814
11,500										11,140	0.0088	13,215,465				11,198	0.0093	11,971,152
12,000										11,624	0.0093	13,062,181				11,684	0.0097	11,979,857
12,500				12,909	0.0076	16,569,589				12,109	0.0098	12,921,669	12,255	0.0076	16,052,252	12,171	0.0103	11,818,791
13,000							12,619	0.0073	17,369,853							12,658	0.0111	11,589,466
13,500																13,145	0.0118	11,393,385
14,000																13,632	0.0124	11,299,258
14,500													14,216	0.0091	15,626,487			
15,000																		
15,500							15,046	0.0093	16,547,325									
16,000																		
16,500													16,177	0.0109	15,034,833			
	Breaking load . . 25,110			Breaking load . . 23,440			Breaking load . . 26,020			Breaking load . . 22,115			Breaking load . . 25,200			Breaking load . . 19,450		
	Per square inch . . 23,757			Per square inch . . 24,204			Per square inch . . 25,258			Per square inch . . 21,423			Per square inch . . 24,706			Per square inch . . 18,938		

Loads Applied.	P. A. 4. Area = 1.0514 square inch.			P. B. 1. Area = 0.828 square inch.			S. B. 1. Area = 0.846 square inch.			P. B. 3. Area = 0.9025 square inch.			P. B. 4 II. Area = 0.7598 square inch.			S. B. 2. Area = 0.837 square inch.		
	Loads per square inch.	Elongation, inches.	E.	Loads per square inch.	Elongation, inches.	E.	Loads per square inch.	Elongation, inches.	E.	Loads per square inch.	Elongation, inches.	E.	Loads per square inch.	Elongation, inches.	E.	Loads per square inch.	Elongation, inches.	E.
500	476	0.0000		604	0.0000		591	0.0000		554	0.0000		658	0.0000		597	0.0000	
1,000																		
1,500	1,427	0.0004	23,777,819	1,812	0.0007	17,253,675	1,773	0.0005	23,649,661	1,662	0.0006	20,146,060	1,974	0.0007	18,801,511	1,792	0.0007	17,067,759
2,000																		
2,500	2,378	0.0013	17,172,869	3,020	0.0014	17,253,675	2,955	0.0011	21,670,604	2,770	0.0013	17,459,918	3,290	0.0018	15,383,177	2,987	0.0014	17,067,759
3,000																		
3,500	3,329	0.0017	19,374,519	4,228	0.0023	16,238,618	4,137	0.0018	20,508,776	3,878	0.0022	15,743,772	4,606	0.0031	13,630,160	4,181	0.0021	17,067,759
4,000																		
4,500	4,280	0.0025	17,701,265	5,436	0.0034	14,923,803	5,319	0.0026	18,858,150	4,986	0.0030	15,501,273	5,922	0.0046	12,416,202	5,376	0.0028	17,067,759
5,000																		
5,500	5,231	0.0033	16,538,794	6,644	0.0046	13,951,927	6,501	0.0033	18,463,757	6,094	0.0041	14,415,624	7,238	0.0062	11,631,163	6,571	0.0036	16,641,065
6,000																		
6,500	6,182	0.0040	16,046,883	7,852	0.0056	13,639,488	7,683	0.0041	17,848,999	7,202	0.0051	13,771,804	8,554	0.0079	10,946,098	7,766	0.0044	16,356,602
7,000																		
7,500	7,133	0.0048	15,852,886	9,060	0.0070	12,923,364	8,865	0.0049	17,409,886	8,310	0.0062	13,311,931	9,870	0.0102	10,218,014	8,960	0.0053	16,027,916
8,000																		
8,500	8,084	0.0063	14,313,869	10,268	0.0085	12,314,381	10,047	0.0059	16,711,192	9,418	0.0073	12,852,324	11,186	0.0127	9,598,955	10,155	0.0062	15,596,457
9,000																		
9,500	9,035	0.0070	14,132,495	11,476	0.0101	11,759,401	11,229	0.0069	16,236,888	10,526	0.0086	12,371,325	12,502	0.0155	9,045,518	11,350	0.0071	15,425,273
10,000																		
10,500	9,987	0.0080	13,670,359	12,684	0.0119	11,273,592	12,411	0.0079	15,795,232	11,634	0.0104	11,767,354	13,818	0.0192	8,501,551	12,544	0.0081	15,020,599
11,000																		
11,500	10,938	0.0091	14,160,164	13,892	0.0138	10,826,581	13,593	0.0088	15,490,434	12,742	0.0115	11,573,510				13,739	0.0092	14,689,502
12,000																		
12,500	11,889	0.0101	12,939,411	15,100	0.0160	10,381,839	14,775	0.0099	15,137,686	13,850	0.0133	11,136,686				14,934	0.0102	14,460,997
13,000																		
13,500	12,840	0.0114	12,506,860	16,308	0.0184	9,970,329	15,957	0.0111	14,700,653	14,958	0.0152	10,728,614				16,128	0.0112	14,223,884
14,000																		
14,500	13,791	0.0128	12,082,043	17,516	0.0212	9,566,257	17,139	0.0123	14,384,789	16,066	0.0171	10,378,838				17,323	0.0123	13,983,702
15,000																		
15,500	14,742	0.0142	11,746,257	18,724	0.0246	9,165,316	18,321	0.0136	14,031,974	17,174	0.0193	10,015,229				18,518	0.0136	13,688,653
16,000																		
16,500	15,693	0.0159	11,351,799				19,503	0.0148	13,770,617									
	Breaking load . . 22,510			Breaking load . . 18,010			Breaking load . . 25,020			Breaking load . . 22,750			Breaking load . . 14,450			Breaking load . . 19,420		
	Per square inch . . 21,409			Per square inch . . 21,756			Per square inch . . 29,574			Per square inch . . 25,207			Per square inch . . 19,016			Per square inch . . 23,201		

Loads Applied.	S. B. 3 II. Area = 0.8432 square inch.			S. B. 4 IV. Area = 1.3478 square inch.			P. B. 5 I. Area = 0.8778 square inch.			P. B. 6 I. Area = 0.9664 square inch.			S. B. 4 II. Area = 0.837 square inch.			P. B. 7 II. Area = 0.7442 square inch.		
	Loads per square inch.	Elongation, inches.	E.	Loads per square inch.	Elongation, inches.	E.	Loads per square inch.	Elongation, inches.	E.	Loads per square inch.	Elongation, inches.	E.	Loads per square inch.	Elongation, inches.	E.	Loads per square inch.	Elongation, inches.	E.
500	593	0.0000		371	0.0000		570	0.0000		517	0.0000		597	0.0000		672	0.0000	
1,000																		
1,500	1,779	0.0006	21,562,876	1,113	0.0003	24,731,657	1,709	0.0008	15,189,486	1,552	0.0006	18,814,000	1,792	0.0005	26,549,859	2,016	0.0011	12,797,378
2,000																		
2,500	2,965	0.0013	19,252,569	1,855	0.0008	19,785,329	2,848	0.0018	13,290,801	2,587	0.0014	15,874,302	2,987	0.0011	23,231,120	3,359	0.0022	12,506,529
3,000																		
3,500	4,151	0.0020	18,482,466	2,597	0.0013	18,686,143	3,987	0.0030	12,025,010	3,621	0.0023	14,213,634	4,181	0.0019	21,278,919	4,703	0.0034	11,920,952
4,000																		
4,500	5,337	0.0029	16,982,792	3,339	0.0019	17,106,065	5,126	0.0042	11,297,183	4,656	0.0034	13,123,959	5,376	0.0028	19,473,140	6,047	0.0050	11,040,284
5,000																		
5,500	6,523	0.0038	16,376,724	4,081	0.0023	16,982,416	6,266	0.0056	10,725,467	5,691	0.0045	12,298,765	6,571	0.0036	18,389,673	7,390	0.0066	10,511,883
6,000																		
6,500	7,709	0.0046	16,118,016	4,823	0.0029	16,400,339	7,405	0.0072	10,088,608	6,726	0.0058	11,575,596	7,766	0.0046	17,420,768	8,734	0.0086	9,879,673
7,000																		
7,500	9,995	0.0056	15,509,668	5,565	0.0034	16,177,290	8,544	0.0091	9,503,927	7,760	0.0072	11,016,932	8,960	0.0055	16,728,693	10,078	0.0109	9,321,449
8,000																		
8,500	11,181	0.0065	15,131,431	6,307	0.0039	15,841,378	9,683	0.0112	8,994,039	8,795	0.0086	10,531,857	10,155	0.0065	16,131,035	11,421	0.0136	8,778,363
9,000																		
9,500	12,367	0.0075	14,767,892	7,049	0.0045	15,580,115	10,822	0.0134	8,570,061	9,830	0.0102	10,080,240	11,350	0.0076	15,602,976	12,765	0.0167	8,276,966
10,000																		
10,500	13,553	0.0088	14,239,870	7,790	0.0052	15,082,032	11,962	0.0161	8,134,985	10,864	0.0121	9,631,550	12,544	0.0087	15,128,808	14,109	0.0210	7,765,440
11,000																		
11,500	14,739	0.0100	13,807,851	8,532	0.0059	14,674,509				11,899	0.0141	9,214,832	13,739	0.0099	14,658,571	15,453	0.0256	7,322,194
12,000																		
12,500	15,925	0.0113	13,417,566	9,274	0.0064	14,575,799				12,934	0.0164	8,821,845	14,934	0.0113	14,148,180	16,796	0.0320	6,886,975
13,000																		
13,500				10,016	0.0071	14,332,631				13,968	0.0191	8,443,610	16,138	0.0127	13,716,305			
14,000																		
14,500				10,758	0.0078	14,065,963				15,003	0.0222	8,078,921	17,333	0.0141	13,325,112			
15,000																		
15,500				11,500	0.0085	13,834,918				16,038	0.0262	7,712,788	18,528	0.0159	12,905,298			
16,000																		
16,500				12,242	0.0092	13,588,527												
	Breaking load . . 20,830			Breaking load . . 34,760			Breaking load . . 17,250			Breaking load . . 20,020			Breaking load . . 24,620			Breaking load . . 14,420		
	Per square inch . . 24,704			Per square inch . . 25,790			Per square inch . . 19,651			Per square inch . . 20,715			Per square inch . . 29,414			Per square inch . . 19,376		

Designation of Specimen.	Area square inch.	Breaking Weight.	Breaking Weight per square inch.	Remarks.
P. B. 2. III.	0.96	10,170	10,594	Broke at a flaw at 10,170 lbs., re-tested and broke at a flaw at 12,240 lbs.
P. B. 8. IV.	1.2276	24,080	19,616	Broke at a slight flaw.
P. B. 9. I.	0.9513	20,050	21,076	
S. B. 5. II.	0.8001	18,890	23,610	
P. B. 10. I.	0.9333	20,050	21,483	
P. B. 11. II.	0.741	16,410	22,146	
S. B. 6. I.	0.8512	24,790	29,124	
P. B. 12. II.	0.725	14,900	20,552	
S. B. 7. I.	0.8385	23,590	28,372	
S. B. 8. I.	0.8645	21,980	25,425	
P. B. 13. III.	0.8624	13,920	16,141	
S. B. 9. III.	1.1063	30,550	27,523	
S. B. 10. III.	1.3275	24,340	18,301	

The following is a summary of the breaking weights of the specimens not cut from the lintels.

P. A. 1	23,757	S. A. 1	24,204
P. A. 2	21,423	S. A. 2	25,258
P. A. 3	18,938	S. A. 3	24,706
P. A. 4	21,409		3)74,168
	4)85,527		24,723
	21,382		
P. B. 1	21,756	S. B. 1	29,574
P. B. 3	25,207	S. B. 2	23,201
	2)46,963		2)52,775
	23,482		26,388

The conclusions which Messrs. Burgess and Vielé draw from these tests are the following, viz. :—

1°. The tensile strength of the iron marked *S* was higher than that of the iron marked *P*.

2°. The elongations for a certain load were greater for equal areas with the grade *P* than with the grade *S*.

3°. Hence *S* was a stronger, but, at the same time, a more brittle iron.

4°. With the same grade of iron, the elongations were greater in planed than in unplaned specimens.

5°. The unplaned specimens in these tests had a less tensile strength per square inch than the planed. They attribute this fact to some slight irregularities in the castings, which were removed by planing.

6°. In regard to the tensile specimens cut from the lintels, it will be seen that specimens marked I. and II. broke at higher loads than those marked IV., and that the weakest of all were those marked III.

TESTS OF THE TRANSVERSE STRENGTH OF WINDOW LINTELS.

All the window lintels tested were of the form shown in the cut (Fig. 31), and all were supported at the ends and loaded in the middle, the span in every case being 52″. From the cut it will be seen that the web varied in height, being 4 inches high above the flange in the centre, and decreasing to 2.5 inches at the ends over the supports. Inasmuch as the section, and hence the moment of inertia of the section, varied, it became necessary to deduce a special approximate formula suitable to determine the modulus of elasticity from the observed deflections.

In order to deduce this special formula, the moments of inertia were first determined at the following five sections, viz.:—

Distance of Section from Support, inches.	Moment of Inertia of Section about Neutral Axis.
26	15.5625
19½	12.2072
13	9.3600
6½	6.9773
0	5.0300

These five values satisfy very nearly the equation:

$$I = \frac{1.8725}{338}x^2 + \frac{6.7875}{26}x + 5.03.$$

Hence this was used for I in the general deflection equation:

$$\frac{d^2v}{dx^2} = \frac{M}{EI},$$

and hence was deduced: $$E = \frac{321.695\,W}{v},$$

where W = load applied, and v = resulting deflection.

A perusal of the results will show that the *P*'s which in tension bore the least were in every case the ones which in the form of lintels stood the most. On the whole, the tensile and the compressive moduli of rupture compare very well with the tensile and the compressive strength of the iron respectively.

The results of the separate tests are given in the following tables:—

Loads Applied.	S. 1. Span, 52″. Weight of lintel, 119 lbs.		S. 2. Span, 52″. Weight of lintel, 116 lbs.		P. 1. Span, 52″. Weight of lintel, 119 lbs.		S. 3. Span, 52″. Weight of lintel, 117 lbs.	
	Deflect, inches.	E.	Deflect, inches.	E.	Deflect, inches.	E.	Deflect, inches.	E.
500	0.0000		0.0000					
1,500			0.0147	21,958,707				
2,500	0.0271	23,785,209	0.0286	22,551,118	0.0331	19,467,170	0.0291	22,109,622
3,500			0.0441	21,952,252				
4,500	0.0557	23,121,053	0.0600	21,522,288	0.0693	18,607,930	0.0598	21,533,476
5,500			0.0759	21,264,309				
6,500	0.0853	22,659,404	0.0923	20,979,580	0.1084	17,890,286	0.0907	21,296,211
7,500			0.1072	21,077,206				
8,500	0.1055	22,320,629	0.1244	20,773,681	0.1484	17,443,935	0.1216	21,177,579
9,500			0.1412	20,593,107				
10,500	0.1363	22,034,361	0.1587	20,377,321	0.1937	16,795,722	0.1557	20,715,611
11,500			0.1760	20,210,429				
12,500	0.1684	21,707,729	0.1938	20,036,531	0.2400	16,309,955	0.1899	20,398,439
13,500			0.2122	19,840,139				
14,500	0.2026	21,290,212	0.2331	19,519,799	0.2927	15,724,039	0.2270	19,961,812
15,500								
16,500							0.2659	19,534,035
	Breaking load 26,750		Breaking load 19,850		Breaking load 27,220		Breaking load 28,670	
	Tensile modulus of rupture . 26,198		Tensile modulus of rupture . 19,433		Tensile modulus of rupture . 26,648		Tensile modulus of rupture . 28,068	
	Compr. modulus of rupture . 80,164		Compr. modulus of rupture . 59,490		Compr. modulus of rupture . 81,578		Compr. modulus of rupture . 85,924	

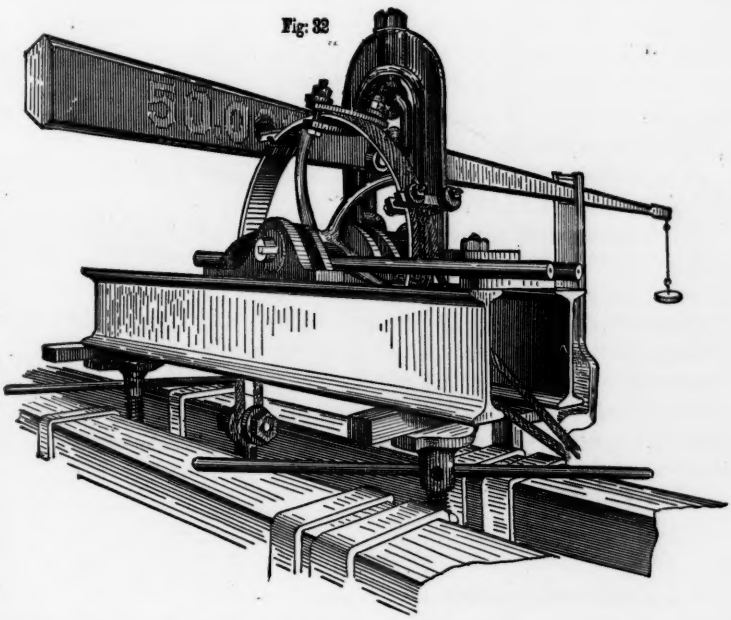
Loads Applied.	S. 4. Span, 52″. Weight of lintel, 118 lbs.		P. 2. Span, 52″. Weight of lintel, 120 lbs.		P. 3. Span, 52″. Weight of lintel, 119 lbs.	
	Deflect, inches.	E.	Deflect, inches.	E.	Deflect, inches.	E.
500	0.0000		0.0000		0.0000	
1,500			0.0149	21,590,272		
2,500	0.0287	22,456,900	0.0307	20,975,359	0.0347	18,541,496
3,500			0.0477	20,291,319		
4,500	0.0588	21,898,268	0.0659	19,637,378	0.0724	17,815,104
5,500			0.0846	19,355,172		
6,500	0.0899	21,712,057	0.1022	19,167,035	0.1150	16,952,791
7,500			0.1204	18,953,963		
8,500	0.1210	21,447,685	0.1403	18,610,508	0.1572	16,521,625
9,500			0.1601	18,343,378		
10,500	0.1544	21,016,559	0.1807	18,070,663	0.2024	16,067,318
11,500			0.2016	17,827,158		
12,500	0.1864	20,844,894	0.2251	17,484,756	0.2522	15,540,516
13,500			0.2492	17,166,571		
14,500	0.2202	20,602,958	0.2730	16,905,859	0.3092	14,932,924
15,500			0.2989	16,605,250		
16,500	0.2637	19,876,418			0.3756	14,277,531
	Breaking load . . 25,120		Breaking load . . 30,520		Breaking load . . 27,200	
	Tensile modulus of rupture . . . 24,592		Tensile modulus of rupture . . . 29,879		Tensile modulus of rupture . . . 26,659	
	Compr. modulus of rupture . . . 75,285		Compr. modulus of rupture . . . 91,467		Compr. modulus of rupture . . . 81,608	

SUMMARY OF THE EXPERIMENTS OF MESSRS. EASTMAN AND GERRISH.

The object of this thesis was to determine the constants suitable to use in the formulæ for determining the strength of the arms of cast-iron pulleys; and also, incidentally, to determine the holding power of keys and set screws.

Some old pulleys which had been in use at the shops were employed for these tests. They were all about fifteen inches in diameter, and were bored for a shaft $1\frac{3}{16}$ inches in diameter.

Fig. 32



Inasmuch as this size of shaft would not bear the strain necessary to break the arms, the hubs were bored out to a diameter of $1\frac{11}{16}$ inches diameter, and key-seated for a key one-half an inch square.

In order to strengthen the hubs sufficiently, two wrought-iron rings were shrunk on them, so as to make it a test of the arms and not of the hub.

The machine used for applying the stress is shown in the cut (Fig. 32).

The pulley under test is keyed to a shaft which, in its turn, is keyed to a pair of castings supported by two wrought-iron *I* beams, resting

upon a pair of jackscrews, by means of which the strain is applied. A wire rope is wound around the rim of the pulley, and leaves it in a tangential direction vertically. This rope is connected with the weighing lever of the machine, and weighs the load applied.

The idea of the arrangement was to get a pull upon the rim of the pulley as nearly as possible like the belt pull, to which it is subjected in practice, and, at the same time, to have some means of weighing this pull. In practice there are two pulls upon the rim, that of the tight side, and that of the loose side of the belt, the sum of the two tending to produce a bending of the shaft and a compression of the rim and arms of the pulley, while the difference of the two causes a rotation of the pulley and a bending moment in all the arms. It will be seen in the arrangement used that while there is no tight side and loose side of a belt, yet there is a compression of both rim and arms, which must be very similar to that caused by a belt, and a bending moment in the arms such as occurs in practice.

In a number of the experiments one arm gave way first, and then the unsupported part of the rim broke.

The breaking load of the separate pulleys was, of course, determined, and then it was sought to compute from this the modulus of rupture of the cast iron, if so it can be called.

The method commonly given for computing the strength of pulley arms is to consider them in one of two ways; viz., either as beams fixed in direction at one end, and loaded at the other, or else to consider them as fixed in direction at both ends, thus making of each arm a pair of cantilevers, half as long as the arm, fixed at one end and loaded at the other.

If we let

I = moment of inertia of section,

n = number of arms,

y = half depth of each arm = distance from neutral axis to outside fibre,

x = length of each arm in a radial direction,

P = breaking load determined by experiment;

then we should have, for the outside fibre stress at fracture,

$$f = \frac{Pxy}{nI}. \qquad (1)$$

Number of Test.	Diameter of Pulley.	Face.	Thickness of Rim.	Width of Hub.	Thickness of Hub.	Length of Arms.	Number of Arms.	Dimensions of Arms; all Elliptic. At Rim.	Dimensions of Arms; all Elliptic. At Hub.	Breaking Weight.	$f_1 = \frac{Pxy}{nI}$.	$f_2 = \frac{Pxy}{2nI}$.	Place and Manner of Fracture.	Remarks.
1	14	4	$\frac{1}{4}$	$4\frac{1}{4}$	$\frac{3}{4}$	$4\frac{1}{4}$	5	$1\frac{1}{8} \times \frac{9}{16}$	$1\frac{7}{8} \times \frac{21}{32}$	5,600			Hub cracked.	Not a test of the arms.
2	15	$3\frac{1}{2}$	$\frac{5}{16}$	$3\frac{13}{16}$	$1\frac{3}{16}$	5	5	$1\frac{3}{8} \times \frac{11}{16}$	$1\frac{1}{2} \times \frac{13}{16}$	5,300			Hub cracked.	Not a test of the arms.
3	$12\frac{1}{2}$	$3\frac{3}{16}$	$\frac{5}{16}$	$3\frac{1}{4}$	$\frac{3}{4}$	$4\frac{1}{4}$	6	$2 \times \frac{7}{16}$	$2 \times \frac{7}{16}$	2,200	24,425	12,212	All the arms broke at the hub.	
4	$12\frac{1}{2}$	$3\frac{3}{16}$	$\frac{5}{16}$	$3\frac{1}{4}$	$\frac{3}{4}$	$4\frac{1}{4}$	6	$2 \times \frac{7}{16}$	$2 \times \frac{7}{16}$	2,100	23,314	11,657	All the arms broke at the hub.	
5	12	3	$\frac{1}{4}$	$3\frac{1}{8}$	$\frac{11}{16}$	$3\frac{1}{2}$	5	$1\frac{5}{16} \times \frac{1}{2}$	$1\frac{5}{8} \times \frac{9}{16}$	6,700	32,160	16,080	One arm broke at rim and hub.	Load subsequently increased to 8,000, when the rim broke.
6	$14\frac{3}{4}$	$3\frac{1}{4}$	$\frac{5}{16}$	$3\frac{3}{4}$	$\frac{17}{32}$	5	6	$1 \times \frac{9}{16}$	$1\frac{1}{4} \times \frac{5}{8}$	4,400	38,245	19,122	All the arms broke at the hub.	
7	15	$3\frac{7}{16}$	$\frac{1}{4}$	4	$\frac{9}{16}$	5	5	$1\frac{5}{16} \times \frac{3}{4}$	$1\frac{1}{2} \times \frac{27}{32}$	4,300	23,060	11,530	One arm broke at the hub.	Load subsequently increased to 5,300, when the rim broke.
8	24	$3\frac{1}{16}$	$\frac{5}{16}$	$3\frac{1}{4}$	$\frac{5}{8}$	$9\frac{5}{8}$	5	$1\frac{1}{8} \times \frac{11}{16}$	$1\frac{9}{16} \times \frac{3}{4}$	2,000	21,430	10,715	One arm broke at the hub.	Load subsequently increased to 2,200, when the rim broke.
9	14	4	$\frac{5}{16}$	$4\frac{1}{4}$	$1\frac{5}{32}$	4	5	$1\frac{1}{16} \times \frac{1}{2}$	$1\frac{7}{16} \times \frac{5}{8}$					One of the arms was broken in driving it on to the shaft, so no test was made.
10	$13\frac{1}{2}$	$4\frac{1}{4}$	$\frac{5}{16}$	$4\frac{1}{4}$	$1\frac{1}{32}$	$4\frac{1}{2}$	5	$1\frac{7}{16} \times \frac{3}{4}$	$1\frac{11}{16} \times \frac{25}{32}$					There was a bushing inside the hub keyed to shaft, pulley slipped on bushing, hence no test.
11	15	$3\frac{7}{16}$	$\frac{5}{16}$	4	$\frac{9}{16}$	5	5	$1\frac{5}{16} \times \frac{3}{4}$	$1\frac{1}{2} \times \frac{27}{32}$	4,300	23,060	11,530		One arm broke at the hub during test of keys.
12	$19\frac{3}{4}$	4	$\frac{1}{4}$	$4\frac{1}{4}$	$\frac{3}{4}$	$7\frac{1}{8}$	5	$1\frac{3}{8} \times \frac{25}{32}$	$1\frac{15}{16} \times \frac{27}{32}$					This pulley was the one used in testing set screws, and also some of the keys, and one of the arms broke during a key test.
									Average		26,528	13,264		

if we adopt the first assumption; or,

$$f = \frac{Pxy}{2nI}, \qquad (2)$$

if we adopt the second assumption.

These formulæ are both based upon the assumption of arms of uniform section, either straight or else symmetrical with respect to hub and rim.

Other formulæ might be deduced which assume a variable section, but it would not seem to be worth while, in view of the fact that the bending moment is probably unequally divided among the arms. Hence the students confined themselves to computing the values of f from each of the above formulæ, thus obtaining average values of the constants to be used in these formulæ for the purpose of determining approximately the strength of the pulleys. (See table of the results on previous page.)

Conclusions from these Tests.

1st. A low value of the modulus of rupture of cast iron should be used in the ordinary formulæ for designing pulley arms, due to the fact that a load at the rim acts more upon some arms than upon others, as shown by the fact that, in four out of eight of the tests, one arm broke first, and this one always occupied the same position.

2d. In every case but one, of these four, a greater load than the original was afterwards put upon the pulley, and no other arm broke, but the rim gave way by crushing. In this one case excepted, the arms afterwards stood a greater load proportional to their number before breaking.

3d. In the tests on the single arms to be described next, the modulus of rupture rose as high as 55,000 lbs. in some cases, and in no case went below 35,000 lbs.

Tests of the Separate Arms.

In the cases of numbers 5, 7, 8, 9, and 10, some of the arms were not broken, the rims were now broken off, and the remaining arms were tested separately, the pull being exerted by a yoke hung over the end of the arm, the lower end being attached to the link of the machine.

The arms were always placed so that the direction of the pull was tangent to the curve of the rim at the end of the arm. The actual outside fibre stress at fracture was then determined by calculation from the experimental results, and is recorded in the following table:—

Number of Arm.	Dimensions of Section at Fracture: all elliptical.	Bend of Arm, with or against load.	Actual Outside Fibre Stress at Fracture.	Average Modulus of Rupture for each Pulley.
5 – 1	$1\frac{9}{16} \times \frac{17}{32}$	against	45,396	45,396
7 – 1	$1\frac{1}{2} \times \frac{7}{8}$	against	36,802	
7 – 2	$1\frac{5}{32} \times \frac{7}{8}$	against	39,537	
7 – 3	$1\frac{17}{32} \times \frac{7}{8}$	with	46,407	40,915
8 – 1	$1\frac{5}{32} \times \frac{13}{16}$	against	35,503	
8 – 2	$1\frac{11}{32} \times \frac{25}{32}$	against	36,091	
8 – 3	$1\frac{11}{32} \times \frac{13}{16}$	with	39,939	
8 – 4	$1\frac{5}{32} \times \frac{13}{16}$	with	42,469	38,500
9 – 1	$1\frac{7}{16} \times \frac{5}{8}$	against	41,899	
9 – 2	$1\frac{7}{16} \times \frac{21}{32}$	against	44,148	
9 – 3	$1\frac{7}{16} \times \frac{5}{8}$	with	55,442	47,163
10 – 1	$1\frac{3}{4} \times \frac{13}{16}$	against	54,743	
10 – 2	$1\frac{13}{64} \times \frac{13}{16}$	against	50,943	
10 – 3	$1\frac{3}{16} \times \frac{13}{16}$	against	38,605	
10 – 4	$1\frac{7}{8} \times \frac{13}{16}$	with	55,229	49,880

Total . . . . 663,153. Average . . . . 44,210.

In order to show how the results in the preceding table were deduced from the experiments, the calculation will now be given in full for the first, or 5–1 (Fig. 33).

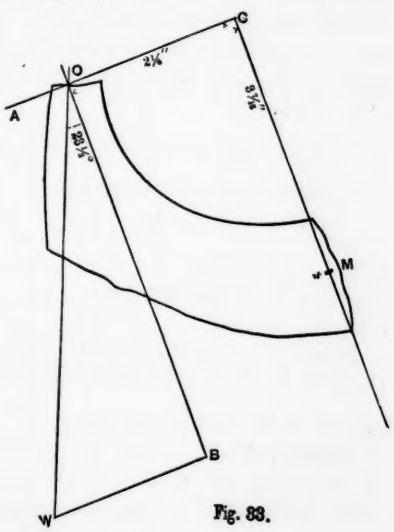


Fig. 33.

The force OW, which is equal to the load upon the arm, is resolved into two components, OB and BW. Both these components act on the arm at the point O, OB in the direction OB, and BW in the direction OA.

The first, OB, acts as a pull at the end of a cantilever of length OC, and is calculated accordingly; the second, BW, acts as a pull in the direction OA, and produces stresses similar to those acting in a hook, where the distance from the line of pull to the centre of the most strained section is CM.

The formula used for the cantilever is

$$f_1 = \frac{My}{I},$$

where M equals the pull times the length of the arm, y equals half the depth, and I equals the moment of inertia of the section.

$$\frac{y}{I} = \frac{32}{\pi bh^2}.$$

The formula used to determine the greatest tension due to the force BW is

$$f_2 = \frac{P}{A} + \frac{Pny}{I},$$

where P equals the pull, A equals the area of the section $= \frac{\pi bh}{4}$, n equals the distance CM, and y equals the half-depth.

The sum of f_1 and f_2 gives us the greatest fibre stress at fracture, or the modulus of rupture of the iron of the arm. The breaking load of this arm was 1645 lbs. Hence:

$$OW = 1645.$$
$$OB = OW \cos 23\tfrac{1}{2}^\circ = 1508.$$
$$BW = OW \sin 23\tfrac{1}{2}^\circ = 655.$$

$$\therefore f_1 = \frac{(1508)\,(2.25)\,(32)}{\pi\,(0.5312)\,(1.5625)^2} = 26671.$$

Also, $$f_2 = \frac{(655)\,(4)}{\pi\,(0.5312)\,(1.562)} + \frac{(655)\,(3.437)\,(32)}{\pi\,(0.5312)\,(1.562)^2} = 18725.$$

Hence $f_1 + f_2 = 45396$, as recorded in the table.

The other values are similarly calculated.

An inspection of the table will show that the modulus of rupture figures out higher when the bend of the arm is with the load than when

it is against it, and the value will be found to be very much higher than the values of f derived for the pulleys with the rims on.

Tests of the Holding Power of Set Screws.

These tests were all made by using pulley No. 12, the pulley being fastened to the shaft by two set screws and the shaft keyed to the holders; then the load required at the rim of the pulley to cause it to slip was determined, and this being multiplied by

$$\frac{9\frac{7}{8}+\frac{5}{16}}{\frac{27}{32}\times 2}=6.037,$$

gives the holding power of the set screws.

The number 6.037 is obtained by adding to the radius of the pulley one-half the diameter of the wire rope, and dividing the sum by twice the radius of the shaft, since there were two set screws in action at a time. The set screws used were of wrought iron, $\frac{5}{8}$ of an inch in diameter, and having ten threads to the inch; the shaft used was of steel and rather hard, the set screws making but little impression upon it. The set screws were set up with a force of 75 lbs. at the end of a ten-inch monkey wrench. The set screws used were of four kinds, marked respectively *A*, *B*, *C*, and *D*. They may be described as follows: —

A, ends perfectly flat, $\frac{9}{16}$" diameter.
B, radius of rounded ends, about $\frac{1}{2}$ inch.
C, radius of rounded ends, about $\frac{1}{4}$ inch.
D, ends cup shaped and case hardened.

The results are given in the following table: —

No. of Test.	*A*	*B*	*C*	*D*
1	1,412	2,747	1,902	2,807
2	2,203	2,747	2,354	1,962
3	2,131	3,079	3,079	2,173
4	2,143	2,958	2,958	2,203
5	2,294	2,897		2,958
6	2,203	3,048		2,717
Average	2,064	2,912	2,573	2,470

The following remarks should be made in regard to each kind of tests.

A. The set screws were not entirely normal to the shaft; hence they bore less in the earlier trials before they had become flattened by wear.

B. The ends of these set screws, after the first two trials, were found to be flattened, the flattened area having a diameter of about $\frac{1}{4}$ of an inch.

C. The ends were found, after the first two trials, to be flattened as in *B*.

D. The first test held well because the edges were sharp, then the holding power fell off till they had become flattened in a manner similar to *B*, when the holding power increased again.

Keys.

The experiments on keys were made with pulley No. 11, except those marked *C*, which were tested with pulley No. 12. In all cases where the keys were not as wide as the keyway they were wedged in with hardened steel pieces, the hardened steel piece in the pulley hub being as long as the hub was wide.

The load was applied as in the other tests, the shaft being firmly keyed to the holders. The load required at the rim of the pulley to shear the keys was determined, and this multiplied by a suitable constant, determined in a similar way to that used in the case of set screws, gives us the shearing strength per square inch of the keys.

The keys tested were of eight kinds, denoted, respectively, by the letters *A*, *B*, *C*, *D*, *E*, *F*, *G*, and *H*, and they may be described as follows: the first dimension being the length, the second the width, and the third the height.

A, were of Norway iron, $2'' \times \frac{1}{4}'' \times \frac{15}{32}''$; constant = 18.5184.

B, were of refined iron, $2'' \times \frac{1}{4}'' \times \frac{15}{32}''$; constant = 18.5184.

C, were of cast or tool steel, $1'' \times \frac{1}{4}'' \times \frac{15}{32}''$; constant = 49.78.

D, were of machinery steel, $2'' \times \frac{1}{4}'' \times \frac{15}{32}''$; constant = 18.5184.

E, were of Norway iron, $1\frac{1}{8}'' \times \frac{3}{8}'' \times \frac{7}{16}''$; constant = 18.5184.

F, were of cast iron, $2'' \times \frac{1}{4}'' \times \frac{15}{32}''$; constant = 18.5184.

G, were of cast iron, $1\frac{1}{8}'' \times \frac{3}{8}'' \times \frac{7}{16}''$; constant = 18.5184.

H, were of cast iron, $1'' \times \frac{1}{2}'' \times \frac{7}{16}''$; constant = 18.5184.

The shearing stresses per square inch, as determined from the experiments, are given in the following table: —

	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*
1	41,202	36,482	100,056	70,186	37,036	34,166	38,700	29,814
2	41,758	37,334	91,344	66,110	37,222	36,944	37,222	38,978
3	40,184	39,254		64,630	36,850	30,278		
4	47,760	39,166		66,574		30,758		
Average	42,726	38,059		66,875	37,036	33,034		

REMARKS.

A. Some crushing took place before shearing.

B. Slight crushing took place before shearing.

C. In the second test one of the wedges slipped and did not bear on the whole length of the key.

E. Inasmuch as these keys were only $\frac{7}{16}''$ deep, they tipped slightly in the keyway.

H. In the first test there was a defect in the keyway of the pulley.

A CRITICAL STUDY OF THE HEATING AND VENTILATION OF THE NEW BUILDING OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

By S. H. WOODBRIDGE, A.M.

II.

Results.

These may be grouped under the heads of Ventilation, Heating, and Cost.

Ventilation. — The average supply per occupant, as indicated by the measured quantity of air moved by the fan, approximates and often exceeds 8000 cu. ft. an hour.

The distribution of air is, however, far from being an equal one. This is due in part to the lack of available flues, the actual flue areas in some important cases falling as seriously short of schedule requirement as in other cases they exceed it. Again, some rooms have an excess of the schedule number of occupants, while others, as the chemical, and most of the physical laboratories, have less than their schedule quota. Furthermore, the necessities of changing work and the increasing number of attending students have resulted in changes in the uses and sizes of rooms for which corresponding alterations in flue apportionment could not be made. In a few cases the result is apparent in a thoroughness of ventilation seriously below the schedule standard.

In general, however, the results, as indicated by a large number of air analyses from the most crowded rooms, have reasonably satisfied the estimates on which the schedule was based. The average of fourteen analyses of air from Room 22 — thus far the most crowded of all the lecture rooms — gives .000864 of carbonic acid for 160 occupants. In each test the air was taken from three or four points within the room, so giving a fair indication of the condition of air within it. In its present overcrowded condition — the attendance on the Second Year Physics lectures being 225 — the mean of four samples of air taken on a muggy and rainy day, when gaslight was required for illumination, gave .00133 of carbonic acid, and on a clear and cool day, when no gas was burned, .00102. The former agrees closely with the results indi-

cated by computation, and the latter is better than computed results by about one part in 10,000. Thus, the total hourly supply to the room being 185,000 cu. ft., and the occupants numbering 225, the quota per occupant is 820 cu. ft. The carbonic acid elimination per occupant being 0.6 cu. ft. per hour, $\frac{6}{820}$, or .00073, is the resulting carbonic acid increment. That due to gas combustion was found to be .00017. The average of several measurements of carbonic acid in the air of the unoccupied room, with full air volume flowing through it, being .00043, makes a total of .00133.

The difficulty of thoroughly ventilating such a crowded room by means of three supply and three discharge flues, unprovided with any special means for the diffusion of supply, and of avoiding the creation of local and sensible draughts, is well illustrated in this case. The room space, excluding furnishings, is not more than 24,000 cu. ft. The sittings are 225, and the space per capita but little over 100 cu. ft. The supply of 820 cu. ft. of air an hour requires a change of air every seven minutes, approximately, and to give the full schedule supply of 1500 cu. ft. would necessitate a change every 3.8 minutes. In the absence of effective means for the diffusion of supply, the occupants of the room are, perhaps, to be congratulated that it is not provided with the schedule flue area.

From these relatively high quantities of carbonic acid found in the most crowded of all the rooms, the proportion of carbonic acid found in others ranges downward to a nearly normal for indoor air — of .0005 or so.

The sensible and disagreeable effect of accumulated dust or vitiating matter on air quality, receives a marked illustration in Rooms 20 and 21. A numerous collection of old plaster and other models; an uncovered library; extended cases with deep recesses for the reception of drawing-boards, etc., and practically inaccessible for the purposes of cleansing; old clothing used by the students while at their work; and the work itself, are doubtless among the sufficient causes for the dusty and close odor peculiar to the rooms, and sometimes complained of as evidence of faulty ventilation. The worst sample of air thus far obtained from the room, though having nearly double the schedule number of occupants, giving but .0007 parts of carbonic acid, points suggestively to the necessity of emphasizing scrupulous cleanliness as a prerequisite to satisfactory results by ventilation.

A determination of the location of the stratum of most vitiated air has been attempted by a series of carbonic acid tests. The disturbing effects of currents aside, its location between ceiling and floor must be

determined by the relative specific gravities of the vitiated and the ambient air. If the supply is warmer than the average temperature of the room, its air must rise to the ceiling and float there, moving toward the outer walls as the air in that vicinity is cooled, falls, and moves across the floor to the outlet.

The total general effect would then be to make the vitiation cumulative from the ceiling to the floor, and from the outer to the inner wall and point of discharge. The argument for downward ventilation when air is cooled in transit is, in part, based on the assumption that the location of greatest purity is coincident with that of highest temperature, and that of the greatest impurity with that of the lowest temperature. The greater the temperature differences, therefore, between the ceiling and the floor, the greater the certainty of the stratification under consideration. The lower the temperature of the air supply, and the more crowded the floor with occupants, — a condition tending to heat the air in transit, — the less the probability of such stratification.

The air tests in two typical rooms give the following results: —

Parts of Carbonic Acid in 10,000.

Experiments,	1st.	2d.	3d.	1st.	2d.
Rooms,	22	22	22	38	38
2 ft. from floor,	10.63	9.67	8.30	7.41	7.55
6 ft. from floor,	?	7.99	8.27	7.38	6.58
10 ft. from floor,	9.96	7.72	?	4.87	5.47
14 ft. from floor,	8.84	7.05	6.97	4.10	5.85

By opening windows under conditions favoring an indraught of cool air, the stratum of greatest vitiation may be raised from the floor to a height proportionate to the depth of cool air so let in. In the early fall and the late spring, the air supply is not infrequently cooler than that of the room — and the effect becomes the same as with open windows, including that of annoying draught.

The best means found for remedying downward cold currents from registers, has been a hopper-shaped boxing of fine wire gauze, so placed before the inlet as to deliver the air with an upward movement of some 45° from the horizontal. By this means the air becomes sufficiently diffused, and, mingled with the warmer ceiling air of the room, is not felt as a continuous draught at any part of the floor. Air supplied by this method to Room 14, when filled by an audience, has been reduced 15° below the mean temperature of the room without causing observed annoyance.

No method is provided for moistening the air supply. The 12,000

sq. ft. of concrete surface forming the sub-basement floor yields a large amount of moisture to the air in movement. This is indicated by its usual dry appearance when the air is moving over it, and its dampening when the ventilating currents are stopped for any length of time; and also by the fact that the relative humidity of the air supply has been found in cold weather to be between 25 and 35 against the 15 or 20 which would have resulted from the increase of temperature without an addition of moisture.

The desired plenum condition within the building is secured by the approximate equality of inlet and outlet area in flues, the velocity of flow through the supply flues being some 60 per cent higher than through those of discharge. The effect of a low outside temperature is, however, sufficient, because of increased rate of upward leakage through the building, to overcome this pressure in the basement and first, and sometimes in the second, stories, and to increase to an equal extent the outward pressure in the third and fourth stories.

The behavior of the chemical laboratory hoods has proved satisfactory in all cases in which the construction corresponds with the description previously given. When the most poisonous or offensive gases are being generated, it is recommended that the hood sashes be drawn down to the stops fixed within two inches of the hood shelf. Large class sections working together, in Room 41, on the experimental production of sulphuretted hydrogen and arsenious gases have found the hoods efficient enough to clear the room from all but moderate traces of the gases.

The plan of ventilating the chemical floor with the air discharged from the four lower stories has been seriously considered. This plan would reduce the air required for the building to two-thirds the present supply, and it would nearly double the supply to the chemical floor. The quality of the air would be but slightly inferior, because of the large aggregate air quantity furnished those stories in proportion to the number of occupants using them.

The objection urged against the sub-basement method of air distribution to flues, on the ground of loss by leakage through the basement floor, has not been realized. The flooring is very tight, but shrinkage has caused it to move away from the walls enough to make caulking necessary. There is a loss of air to the flues by air movement through this variable crevice, and the many imperfectly filled cuts made through the floor for piers and other purposes; but the loss is small because of the low plenum pressure, which does not exceed $\frac{1}{8}$ inch water column, and the leakage is not lost, as it passes by the usually open doors of the basement to the hall, and thence to the chemical story.

Heating.—The prediction, by some, of great difficulty in heating so large and so exposed a building by the indirect method, has not been verified by experience. In general, the difficulty has been greatest in those parts of the building in which the rates of air change are least, and least where the rates of change are most rapid. Thus the temperature of the basement, having a relatively small air supply, and being further subject to chill by the inward leakage of cold air, has, in extreme weather, been too low for other than laboratory work, unless warmed by a super-heated sub-basement. Three or four rooms having an exceptionally small air supply and unfavorable exposure are furnished with supplementary direct heating surface.

The uniformity of temperature from floor to ceiling is greatest in those rooms in which the rate of air change is most rapid, and its temperature proportionately low, and least under the reverse conditions of supply.

Room 21 is 100′ × 30′ × 15′, and has a western and corner exposure, and five windows equivalent to 100 sq. ft. each. An air volume equivalent to its cubic contents is passed through the room every twelve minutes. On the morning of the second of two days of 10° above zero weather, and with moderate westerly wind, the temperatures in various parts of the room were found to be as follows:—

South end of room at	5	ft.	from	floor,	71.6°;	at ceiling,	73.4°.
Southwest corner,	"	"	"		72.5°.		
West wall 30′ to north	"	"	"		73.4°.		
" 60′ "	"	"	"		73.4°.		
North end	"	"	"		71.6°;	"	75.2°.

The room was slightly overheated, especially in the middle part, due to the abnormally high temperature (92°) of the air issuing from a register in that vicinity.

Room 16, on the first floor and east side of the building, is 80′ × 30′ × 15′, and has the air changed once every twenty minutes or so. It has some 500 sq. ft. of window surface, and the inward leakage through them in cold weather is large. A series of temperatures were observed in it on the same day and under similar conditions with those taken in Room 21, and with the following results:—

Middle of room at	floor,				64.2°.		
" " "	7	ft.	"		67.8°.		
" " "	15	ft.	"		74.8°.		
" " "	5	ft.	from	floor,	west side, 66.2°;	east side,	65.8°.
Southeast corner	5	ft.	"		64.4°.		
Floor ventilators,					west side, 63.0°;	east side, 61.2°;	southeast side, 61.2°.

To the east and southeast outlet ventilators the air comes in part off neighboring windows, which accounts for the exceptionally low temperature of the air passing through them.

These two rooms are cited as typical of the two classes of the fairly rapid and the fairly slow rate of ventilation. There remain those of lower rate, spoken of as requiring direct heating, and others of higher rate, into which air enters but little exceeding, and sometimes below, the mean temperature of the room.

The most serious difficulty thus far met in the use of the system has been found in maintaining the building's warmth without the use of the fan. Thus, when the building is closed for the night, the leakage outward at the top and inward at the bottom results in a continuous upward flow through the supply flues to the upper stories, and a reversed movement through the flues which connect the lower rooms with the sub-basement. The air which leaks in through windows and walls of the lower stories passes to the sub-basement through their supply flues, and thence to the top stories of the building. The result of the derangement is that the lower stories are exposed, in severe weather, to an excessive chill, and the upper ones to overheating. The opening of all doors, including those of the fan room, into the hallway partially relieves the derangement by making it the distributor of warm air to the rooms; but the movement of warm air to the upper rooms still remains in excess, and the cold air movement from the lower rooms to the hall largely exceeds the reverse movement of warm air from hall to these rooms.

The maintenance of the building's warmth at night, and the warming it in season for its earliest users and classes, remained for a time so difficult as to be responsible for the query whether a mistake had not been made in not providing direct radiation for night and recess heating, and as auxiliary for purposes of quick and effective heating.

Computation making it appear that economy in the use of heat strongly favored a forced method of heating in the early morning, rather than the alternative of moderate all-night heating, the engineer was persuaded to try the method, and to heat by a rapid rotation of air through the building by means of the fan. To effect this, the air is forced through the supply flues to all the rooms, and returned to the rear of the fan through the hallways and Room 6. The result is most satisfactory in the early comfortableness and uniformity of room temperature over the entire building, in the less time required for heating, and in the reduced cost. Formerly the steam was turned into the heating system of the New Building some two hours earlier than into

that of the Rogers (which is heated by the indirect method), whereas the order of time is now reversed, as well as the satisfactoriness of results.

This study and experience points to the desirability of so constructing an indirect system as to facilitate the quick heating of buildings by a sure and rapid rotation of air through the heating system, whether the air movement is effected by gravity or mechanical means.

The effect of a strong wind in cold weather is felt, as in all methods of heating, in chilling the most exposed windward rooms, but not in sensibly diminishing the rate of supply to the room. The effect of wind pressure may be to a considerable extent neutralized by such a disposition of the dampers at the bottom of the supply flues as to force an excess of the plenum air to the windward side of the building. Notwithstanding the fact that the general construction of the New Building, as compared to the Rogers, exposes it to a more rapid rate of cooling, yet so far as known the causes for complaints of cold rooms, due to inability to heat them, have of late been no more frequent from the former than from the latter.

The present most serious defect in the entire heating system lies in the inability to properly control the sub-basement temperature. The large area over which the supplementary system is extended, and the open character of the boxing about the coils, together with the large and more or less exposed surface of the supply and return mains and connections, yield sufficient heat to raise the temperature of the air some 20° in its movement from the fan to the most remote parts of the sub-basement. As Room 40, with other rooms, requires a lower temperature of supply than 70°, it becomes necessary to keep the fan room temperature so low as to make the comfortable heating of the basement and near rooms at times difficult. The sufficient remedy would seem to be in the better covering of the distributing pipes, and the more complete boxing of the supplementary coils.

The loss of heat in the movement of air through outside wall flues is marked in every case in which such flues are used to supply air to the fourth story. In severely cold weather the air in such flues on the windward side of the building suffers a loss of 20°, and under ordinary conditions of working it may be put at from 10° to 15°. The flues are built of a single course of brick within an outer wall of 8″, from which it is separated by a 2″ air space. They are rough finished on the inside, and without metal lining, as are all the flues in the building.

The Cost. — The cost of heating and ventilating the New Building, aside from that of construction already noted, is not easy of exact determination. The boilers which furnish the steam have other and variable

duties. The steam supplied to the New Building is not all used for heating purposes, and about 50 per cent of that used for such heating up to this time has been exhaust from engines and pumps.

The nearest approach to accuracy has been in measuring the water supplied to the boilers, and also that condensed in the heating system, by means of the registering apparatus and tested metres. By this means the proportion of the total steam generated in the boiler in question and used in heating the New Building, may be closely approximated. Corrections may then be made for the loss of heat in work done by the steam in passing through the engine and pumps. The corrected proportion of steam gives at once that of coal, and therefore the cost.

The records of the school year 1887–8 are the most complete of any entire year to date, and the season was the most severe of any since the building has been in use. From the corrected records of that year it appears that 51 per cent, or 314 tons, of the coal burned under the high pressure boilers, must be credited to the heating and ventilation of the New Building.

Cost of Ventilation. — It is desirable, if practicable, to separate the cost of ventilation from that of heating. This could be done if the results reached in the building could be compared with those of another and exactly similar building heated without ventilation.

The Rogers Building, of nearly equal size and exposure, affords a valuable, though not altogether satisfactory, means of comparison. The walls of the New Building are lighter than those of the Rogers; its ratio of window surface is much larger; its leakage about windows, doors, and roof is freer; its walls are bare, while those of the Rogers are plastered, and its floors are without the protection of a plastered ceiling beneath.

The simple heating of the New Building would therefore be more costly than that of the Rogers, as may be further shown by a comparison of the rates of cooling of rooms selected with reference to similarity in location and exposure.

Steam was shut off both buildings at the same time, about 4.45 in the afternoon, the rooms being all at nearly 70°.

Rogers Building.					New Building.				
Room.	4.45 P.M.	7 P.M.	11 P.M.	2 A.M.	Room.	4.45 P.M.	7 P.M.	11 P.M.	2 A.M.
13	70°	66°	59°	53°	10	70°	58°	56°	53°
15	70°	66°	64°	62°	16	70°	57°	57°	50°
21	70°	63°	60°	58°	21	70°	60°	58°	54°
27	70°	72°	70°	68°	24	70°	60°	56°	52°

The rate of first two hours' cooling is of chief importance as indicating the rate of the cooling of the *air* of the room. The later cooling rate is that of the walls, after the air has become chilled to a point at which it absorbs heat from the walls almost as rapidly as it yields it to the cooling surfaces and inward leakage of air. Rough measurements indicate a leakage on a moderately cold night of 120,000 cu. ft. per hour each for the basement and first story, and 80,000 for the second, of the New Building.

Beside these advantages in favor of the Rogers Building should be noted the fact that the boilers are within it, and the boiler chimneys, the escaping heat from which is not without its considerable effect in warming the Rogers Building. But a few of its rooms are freely ventilated. As shown by the following table and discussion, the coal required for the Rogers Building during the year under consideration was about 70 per cent of that credited to the New.

An explanation of this small difference is offered in the following argument. A building, the floors of whose rooms warmed only by superheating the ceiling air, or whose top stories are overheated for the sake of comfort on the lower floors, must have a higher mean temperature than a building in which the temperature is uniform throughout. The loss of heat through walls is directly as the difference between the mean inside and the outside temperatures. The leakage inward of cold and the outward leakage of warm air varies with the weight of equal volumes of inside and outside air. In case of elevated upper for comfortable lower temperatures, the outward leakage is superheated air. The more rapid the inward leakage of cold air, the higher the ceiling or upper temperature must be forced with a corresponding effect on the rate of loss. The frequently noticed open windows of the upper stories of the Rogers Building is evidence in point. The heat loss attending the common method of securing comfortable warmth at the floor by overheating the ceiling, and the further loss peculiar to a building whose several floors and many rooms are connected by an open stair well and open doors, and which is liable to an overheating of top stories for the sake of warmth on the lower floors, may be largely reduced by securing a uniformity of temperature throughout each room and the entire building. It is for this reason that the cost of passing large air volumes at a low temperature through a building is so largely compensated for by reduced loss of heat through its walls, and by the reduced temperature and quantity of leakage.

The following is a summary made up from the daily records, together with the method of computation by which the cost of the ventilation is estimated: —

M. T. indicates mean temperature.
M. C. indicates mean cloudiness on the scale of 10.
W. T. indicates total wind travel in miles.
C. B. indicates total pounds of coal burned under the high pressure boilers.
W. C. indicates the total number of cubic feet of water condensed in the heating system of the New Building.
R. indicates the pounds of coal burned to each cubic foot of water condensed in the heating system of the New Building.

1883–4.

	M. T.	M. C.	W. T.	C. B.	W. C.	R.
October . . .	47.4	6.30	6777	141066	5000	
November . .	42.5	5.30	7682	258446	7000	
December . .	28.7	3.90	7450	110046	10000	
January . . .	23.8	6.10	8674	238540	17000	
February . . .	31.0	7.70	7590	186280	13000	
March . . .	33.5	6.50	8754	183386	11708	
April	42.7	6.50	7995	125546	7755	
May	53.8	5.00	7795	50980	2377	
	37.9	5.9	62717	1294290	73840	

1884–5.

	M. T.	M. C.	W. T.	C. B.	W. C.	R.
October . . .	52.3	5.00	9288	94500	3825	24.70
November . .	41.1	4.70	8732	91500	8057	11.30
December . .	33.1	6.00	8730	158058	14460	11.08
January . . .	27.0	5.20	10769	182400	16103	11.01
February . . .	20.5	4.40	9244	198900	19385	10.02
March . . .	27.9	4.70	10267	172246	11605	13.50
April	46.5	4.00	9323	88500	6000	11.06
May	52.3	5.50	7811	69300	2815	24.30
	37.6	4.94	74164	1055404	82250	

1885–6.

	M. T.	M. C.	W. T.	C. B.	W. C.	R.
October . . .	51.1	5.60	7395	85800	3280	26.16
November . .	43.7	6.28	9338	92435	7390	12.59
December . .	32.8	5.87	10856	149536	15424	9.64
January . . .	26.0	5.86	9323	175700	18032	9.80
February . . .	26.6	5.45	10621	168000	15326	10.96
March . . .	33.7	5.95	10628	152519	14114	10.95
April	48.2	5.36	7664	99808	5156	19.39
May	51.6	5.33	8640	72900	1901	38.35
	39.8	5.61	74465	956892	80623	

1886–7.

	M. T.	M. C.	W. T.	C. B.	W. C.	R.
October . . .	51.5	4.00	8558	94200	3100	35.22
November . .	42.8	4.50	8584	103700	7700	14.71
December . .	28.8	5.90	9933	187200	17300	10.82
January . . .	25.9	6.00	9865	212300	18000	11.89
February . . .	28.9	5.90	9456	182200	14400	12.81
March . . .	31.6	6.10	10755	193800	15000	12.07
April	43.9	4.90	9315	138000	8300	16.41
May	59.3	4.10	7458	75000	2600	28.84
	39.1	5.19	73924	1186400	86400	

1887–8.

	M. T.	M. C.	W. T.	C. B.	W. C.	R.
October . . .	51.0	5.50	7474	144000	3707	38.80
November . .	41.6	4.20	8462	109500	8236	13.30
December . .	32.1	5.90	8313	175400	13217	13.37
January . . .	20.0	4.40	10417	214300	21990	9.74
February . . .	28.4	4.80	7520	185100	17493	10.60
March . . .	32.0	5.70	11433	190200	11161	17.00
April	42.2	4.40	8205	146100	5595	26.10
May	52.5	6.90	6884	126300	2931	43.10
	37.5	5.20	68738	1230900	84330	

Notes from Boiler and Meter Records for 1887–8, with Discussion.

	1 Cubic feet of water fed to boilers Nos. 3 and 4.	2 Condensed in Main Coil.	3 Condensed in Supplementary Coils.	4 Nos. 2 and 3.
October . . .	16,958	1,611	2,096	3,707
November . . .	15,171	4,203	4,033	8,236
December . . .	18,256	8,897	4,320	13,217
January . . .	30,742	12,760	9,230	21,990
February . . .	25,330	8,423	9,070	17,493
March	20,460	4,541	6,620	11,161
April	20,282	1,000	4,595	5,595
May	18,224	261	2,670	2,931
	165,223	41,696	42,634	84,330
Corrected . . .	160,723	41,696	40,371	82,067

As boilers 1 and 2 are "blown off" once a week, the volume of water, 4500 cu. ft. for the year, must be deducted as not evaporated. The corrected evaporation is then 165,223 − 4500 = 160,723 cu. ft.

Column 2 requires no correction, the metre correction appearing in the figures given.

The steam condensed in the supplementary system has been almost entirely exhaust from the engines and pumps, a considerable part of the time, even for the winter months, that steam being in excess of the quantity required. As such steam has yielded part of its heat in the work done, correction for that loss of heat is made as follows. It is assumed that an average of 50 lbs. of steam per hour per H.P. passes through the engine. The total weight of steam so passed and condensed in the New Building during the year is 2,558,040 lbs., which, divided by 50, gives 51,160 as the total work done in H.P. hour units. The theoretical heat equivalent of an H.P. hour being 2564 thermal units, the heat taken from the steam equals $\frac{2564 \times 51{,}160}{966 \times 60}$, or that required to evaporate 2263 cu. ft. of water at 212°.

Therefore 42,634 − 2263 = 40,371 is the corrected value for column 3, and 41,696 + 40,371 = 82,067 the corrected value of column 4.

The fractional part of the water evaporated in, and the coal burned under, boilers 3 and 4, chargeable to the heating and ventilation of the New Building, is then 82,067 ÷ 160,723 = .509.

The coal burned under 3 and 4 during the year was 1,230,900 lbs., which multiplied by .51 gives 627,759 lbs., chargeable to the heating and ventilation of the New Building.

The coal burned under boilers 1 and 2 for heating Rogers Building was 396,900 lbs. But to this must be added the coal burned under 3 and 4 for steam used to heat Rogers Building through the warm months of October and May, and half of the months of November and April, besides the warm half-days of winter, disregarding the room (12) continuously heated by steam from the high pressure boilers 3 and 4.

Assuming that the ratio of condensation rate for the two buildings is a constant throughout the year, and that the evaporation per pound of coal is the same for the two sets of boilers, it is found from the condensation in the New Building for October, one half of November, one half of April, and May, that the coal equivalent for the Rogers Building is 80,700 lbs. Adding this to 396,900, we have 477,600 as the total used in heating the Rogers Building, against 627,759 chargeable to the New Building, and 627,759 ÷ 477,600 = 1.31, gives the per cent of coal required by the New as compared with the Rogers Building.

This, then, represents the comparative cost of heating the Rogers and heating the air required for the warming and ventilation of the New Building, but it does not include the steam used in driving the fan at times when little or no steam is used for warming the air. If this time be assumed as 60 days, the H.P. 14, and the steam per hour per H.P. as 50 lbs., the coal consumption for power for the fan becomes 52,500 lbs. Adding this to 627,759, we have 680,259 as the total to be charged to the New Building, and $680,259 \div 477,600 = 1.42$, the per cent when the cost of running the fan is included.

The mean rate of evaporation per pound of coal is found to be $160,723 \times 60 \div 1,230,900 = 7.85$ lbs.

The principal points of the foregoing discussion of records may be summarized as follows: —

1. The proportion of the coal burned appearing in the condensed water returned from the New Building is 51 per cent of the total burned under boilers Nos. 3 and 4.

2. The ratio of this quantity to that of the coal burned under boilers Nos. 1 and 2 is as 1.58 to 1.

3. The ratio when corrected for coal used under 3 and 4 for heating Rogers Building becomes 1.31 to 1.

4. The ratio when further corrected for coal burned for driving the fan becomes 1.42 to 1.

5. If the ratio be again corrected on the basis of "live steam" used, — that is, by counting out the coal used for required power aside from that expended in driving the fan, — the ratio becomes .67 for the New to 1 for the Rogers Building.

No. 3 gives the best basis of comparison of cost between the simple heating and the heating and ventilation of such a building when mechanical means are not employed.

Assuming that the New Building may be warmed at no greater cost than the Rogers, on the basis of No. 4 it appears that the actual cost in coal of the ventilation of the New Building may be put at $477,000 \times .42 = 200,592$ lbs., or 100 tons of coal, or $500, or something in excess of one dollar a year per occupant.

APPENDIX.

To some readers the significance of the carbonic acid determinations mentioned in the foregoing pages, as a measure of atmospheric purity or vitiation, may not be apparent.

The normal or out-of-door air of Boston contains from 3.3 to 4 parts of carbonic acid in 10,000 of air. An increase of 3 parts of carbonic acid, by respiration, in 10,000 of air is not likely to be accompanied by any sensible odor or evidence of closeness in a clean room, and in the dry indoor atmosphere of a New England winter. Under such conditions, therefore, air which contains no more than 7 parts of carbonic acid in 10,000 may be regarded as pure as it is the required function of good ventilation to maintain it within school buildings or assembly-rooms.

To keep the carbonic acid increment of an enclosure down to the standard of 3 in 10,000 parts of air, 2000 cu. ft. of air an hour per occupant must be supplied, the assumed action of ventilation being a complete dilution of the exhaled breath with the air supplied.

A comparison of the air of the New Building with a few of the many samples secured within the same period of experimentation from other buildings, may assist to a clearer understanding of the degrees of success attained in the former. The carbonic acid will be given in 10,000 parts of air.

During the semi-annual examination of 1883–4 tests were made of the air in two of the then unventilated rooms of the Rogers Building, with a similar room in the New.

New Building.

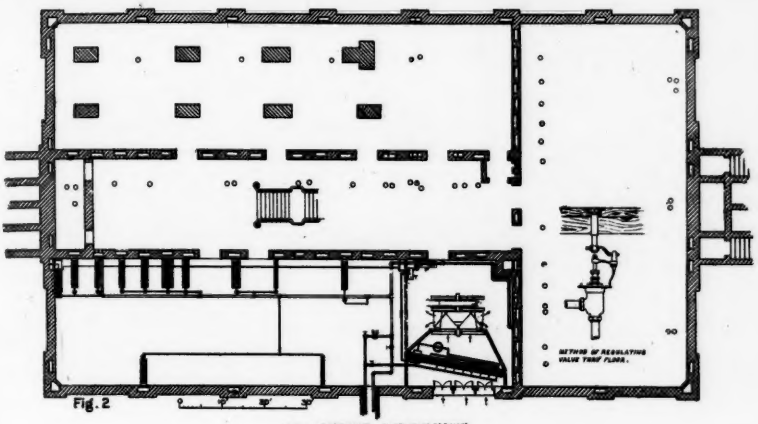
Room 38.	32 occupants.	Carbonic acid	5.3 to 5.21

Rogers Building.

Room 22.	32 occupants.	Carbonic acid	10.59 to 9.44
Room 26.	32 occupants.	Carbonic acid	12.34 to 11.36

According to the method of seating for examination, only half the sittings in each room were filled. With an outside proportion of 3.43, as actually determined, the corresponding mean increment for filled rooms would be, for Room 38, 3.64; Room 22, 13.16; Room 26, 16.88.

The open doors of examination hours, favoring the rooms of the Rogers Building, served to reduce the difference between the contrasted rooms.



PLAN OF BASEMENT - PART OF FLOORING REMOVED TO SHOW SUPPLEMENTARY COILS.

Fig. 1.

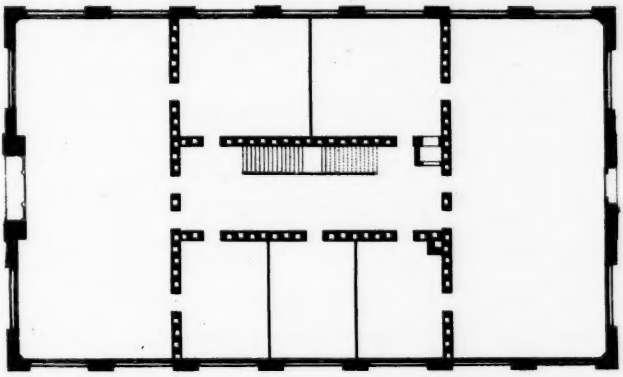
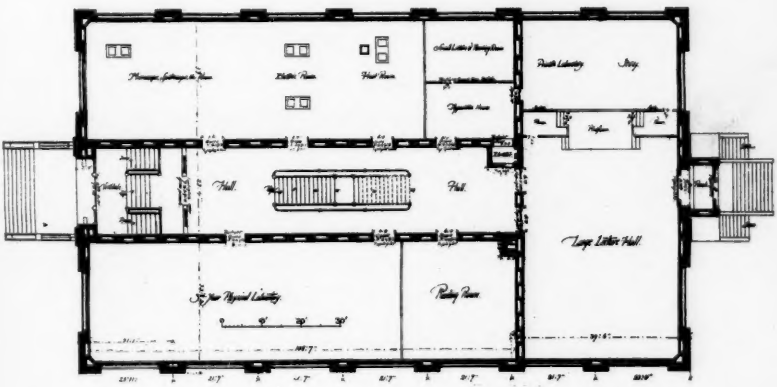


Fig. 9.



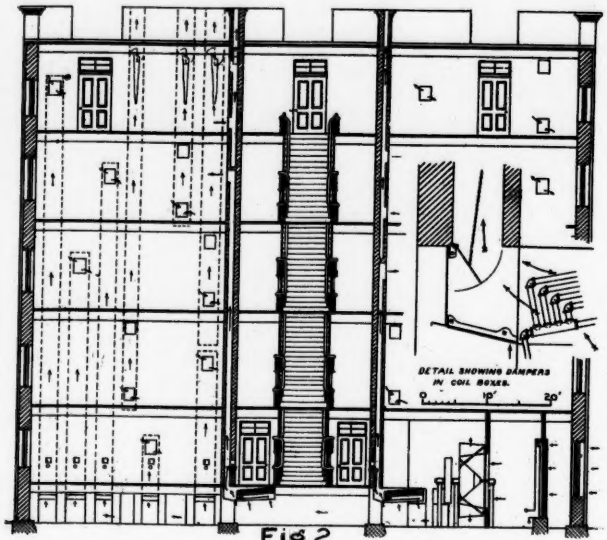


Fig. 2.

ELEVATION OF CROSS WALL

CROSS SECTION THRO' FAN ROOM.

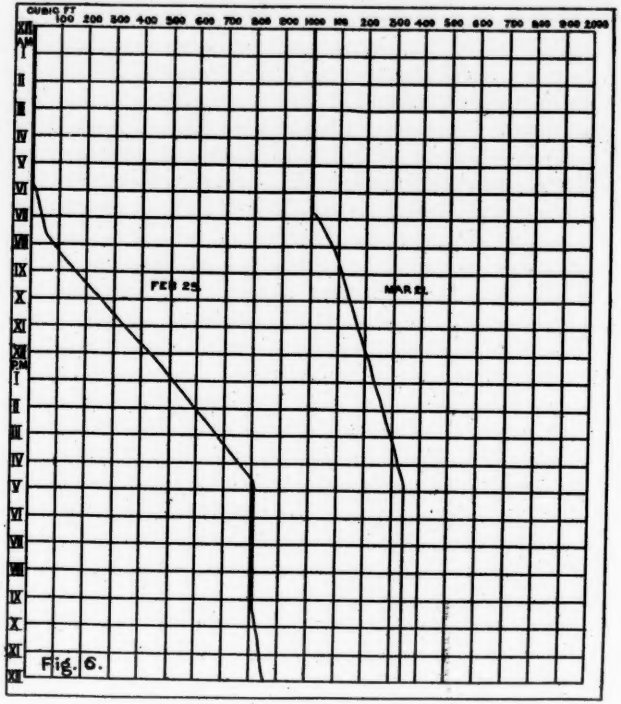


Fig. 6.

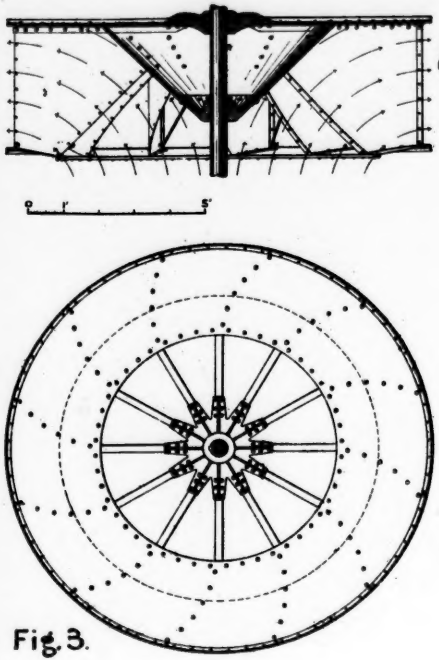


Fig. 3.

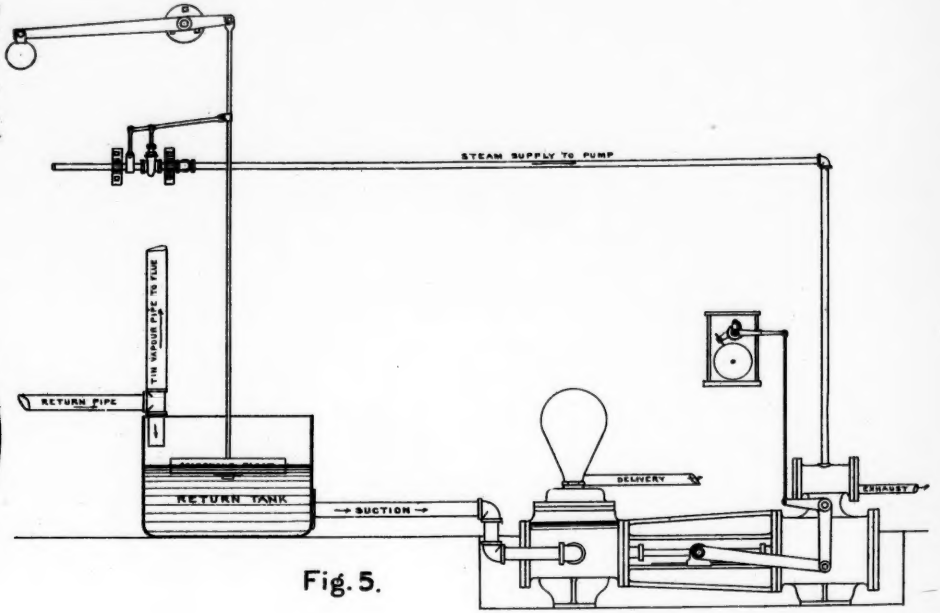


Fig. 5.

Heliotype Printing Co. Boston.

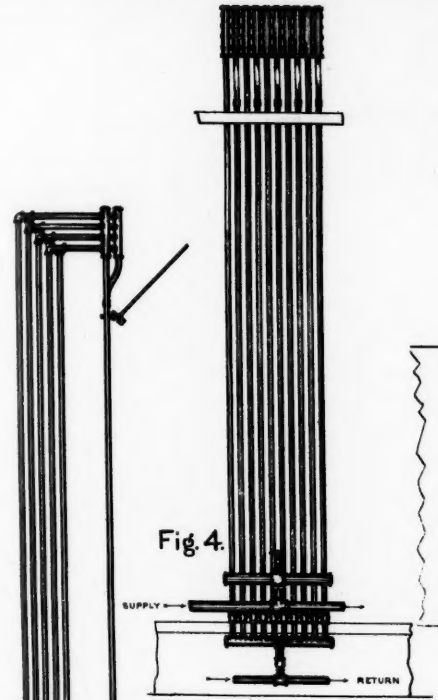
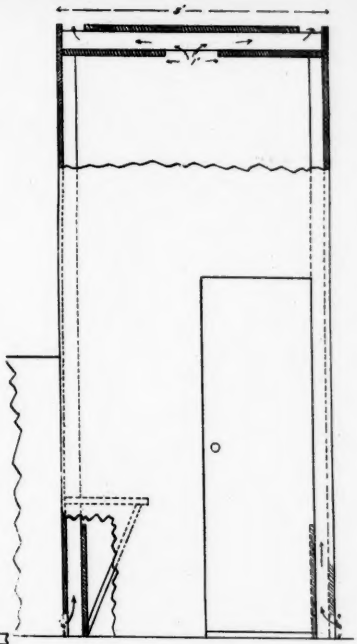
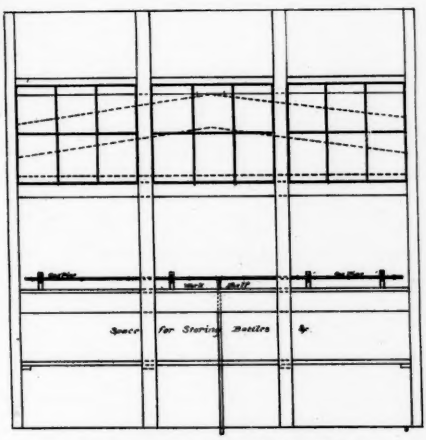


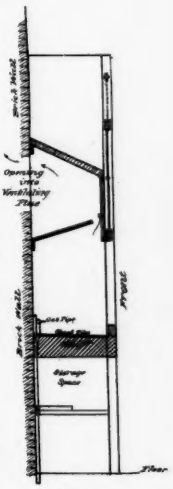
Fig. 4.



End Elevation of Photometric Room
Showing Method of Ventilation
Scale 1in = 1 Ft.

Fig. 8.





Front Elevation of a Hood in Chemical Lab.
The front is fitted with vertically sliding window sashes, breaking down to shelf.

Section

Fig. 7.

HALLS.

Huntington Hall.	Ventilating apparatus used to full	12. to 9.
	Ventilating apparatus unused	18.48 to 17.24
Young Men's Christian Association		36.43 to 32.59
Music, balcony, near door with indraught		13.93
City Hall, council chamber, two-thirds full,	floor	14.60 to 10.12
	gallery	18.58 to 13.22

CHURCHES.

Trinity,	Prior to change in method of heating and ventilating, gallery,		12.43 to 12.24
	After change in method of heating and ventilating,	floor,	17.09 to 14.76
		gallery,	20.52 to 19.12
Harvard, Brookline, floor			18.19 to 17.09

SCHOOLS.

Harvard, Cambridgeport, different rooms and times	23. to 10.8
Blossom Street School, Boston, mechanical ventilation, rooms not full	14.5 to 9.64
Newton Centre, primary, rooms not full	10.99 to 9.88
High School, Taunton	11.39 to 7.47
Chauncey Hall	11.26 to 7.16

THEATRES.

	Floor.	First balcony.	Second balcony.	Gallery.
Boston, full, 1st test				48.7
Boston, full, 2d test	39.13	42.86	44.72	48.14
Boston, full, 3d test		35.48		45.12
Globe, three-fourths full	23.38	35.88	34.59	
Globe, one-half full	19.	24.16	24.72	
Museum, two-thirds full		17.51	21.97	
Hollis Street, two-thirds full,	20.23	16.16	21.97	

Y. M. C. A. BUILDING.

Reading-room	11.66
Gymnasium, running track	11.38
Gymnasium, floor	11.52

Room 24, New Building, being complained of in March, 1885, as having, by contrast with other rooms, a seemingly inferior ventilation, tests were made with the following results:

Number of occupants 40. S.W. corner, 4.96. N.E. corner, 5.53.
Number of occupants 43. S.W. corner, 4.90. N.E. corner, 6.70.

The room's use as a drawing-room tends, as with Room 21 already noted, to a close odor.

It is a matter of sufficient interest to note that the air in movement from the fan to and through empty rooms acquires a carbonic acid increment of from 1 to 1.25 parts in 10,000.

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